THE ROYAL SOCIETY OF TASMANIA

THE ADVANCEMENT OF KNOWLEDGE

Papers and Proceedings of The Royal Society of Tasmania

Edited by Dr Sally Bryant AM
and published by the Society

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December 2024

The Royal Society of Tasmania acknowledges, with deep respect, the traditional owners of this land, and the ongoing custodianship of the Aboriginal people of Tasmania. The Society pays respect to Elders past and present.

We acknowledge that Tasmanian Aboriginal Peoples have survived severe and unjust impacts resulting from invasion and dispossession of their Country.

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Cover Image: newly described species of lichen *Catinaria macrospora* collected in Tasmania's Central Plateau on pencil pines *Athrotaxis cupressoides*. Photograph: Jean Jarman

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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA

VOLUME 158

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THE ADVANCEMENT OF KNOWLEDGE

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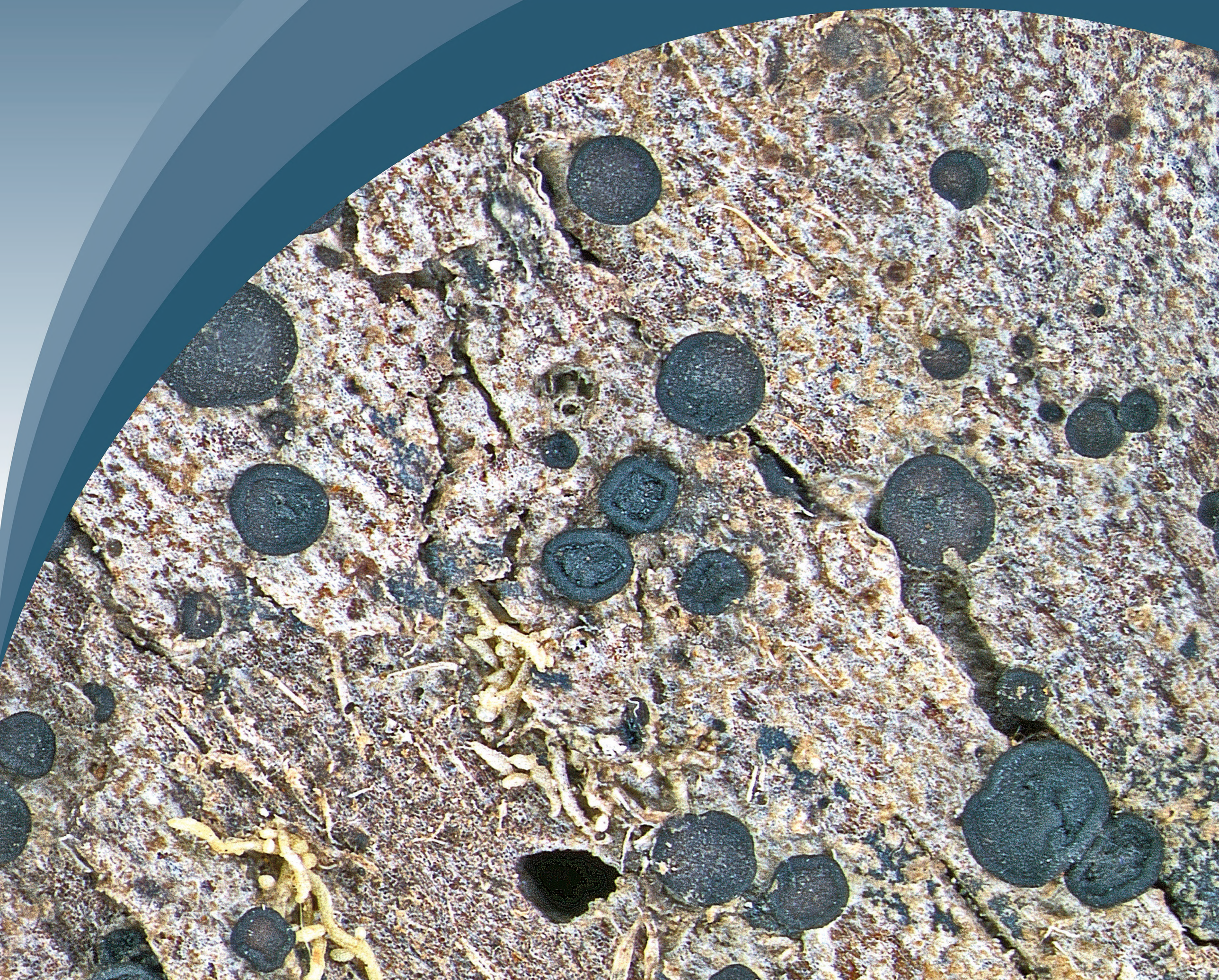


THE ROYAL SOCIETY OF TASMANIA

THE ADVANCEMENT OF KNOWLEDGE

THE PLACE OF ART IN SOFT DIPLOMACY: THE JOURNEY OF A PAINTING FROM THE ROYAL SOCIETY OF TASMANIA ART COLLECTION TO THE UNITED STATES DURING WORLD WAR II

by Mary E Koolhof

(with three plates)

Koolhof, ME (2024). The place of art in soft diplomacy: the journey of a painting from the Royal Society of Tasmania Art Collection to the United States during World War II. *Papers and Proceedings of the Royal Society of Tasmania*. 158: 1–5. ISSN: 0080-4703. Royal Society of Tasmania, GPO Box 1166, Hobart, Tasmania 7001, Australia. Email: admin@rst.org.au

A painting from the Royal Society of Tasmania Art Collection travelled to the United States of America in 1941 as part of an exhibition intended to showcase 150 years of Australian art. The exhibition, curated by Professor Theodore Sizer, featured 144 major artworks sourced from leading Australian art galleries, museums and private collections including the RST watercolour by FG Simpkinson de Wesselow of *Kangaroo Bay, Hobart*, 1846. Opening just two months before America entered World War II, the highly successful exhibition ran until 1945 visiting 26 venues in America, with selected works also touring to seven venues in Canada. It served not only to significantly improve awareness about Australian life but strategically encourage a closer US–Australia relationship for the Australian–American military alliance.

Key Words: colonial art, Royal Society of Tasmania, Simpkinson de Wesselow, Sydney Ure Smith, Australia, United States of America, World War II, Theodore Sizer.

A watercolour painting from the Royal Society of Tasmania (RST) Art Collection made its way to the United States of America in 1941, playing a part in an intriguing piece of mid-war soft diplomacy. The project was ambitious, with an Australian committee headed by Will Ashton OBE, aiming to select about 100 works of Australian art to tour America and Canada. The committee was advised by the highly-credentialled Professor Theodore Sizer, head of the Faculty of Art History at Yale, Director of the Yale University Art Gallery, member of the International Committee on Art History, and one of the most respected art advisers of the Carnegie Corporation at the time. Finance for the American exhibitions was provided by the Carnegie Corporation of New York (*The Herald*, 6 February 1941, p. 7).

The planned exhibition aimed to showcase 150 years of Australian art to the American and Canadian public. Professor Sizer and the Australian committee of representatives from the leading art galleries in the country were tasked with giving a clear picture of Australia in its various aspects and at different periods in its development, as well as depicting the daily life of its citizens (*The Age*, 12 March 1941, p. 8). Sizer travelled to Australia, visiting each of the six state capitals and Canberra: '– all by air – covering a distance as great as from New York to San Francisco and back. It came as a shock to some that Australia was as large as the United States,' it was noted in press coverage of his visit (*The Age*, 12 March 1941, p. 8).

The committee managed to complete its apparently herculean task, selecting artworks from the Sydney, Melbourne, Adelaide, Perth, Hobart, Brisbane and Warrnambool art galleries and museums, the Royal Society of Tasmania collection, the Mitchell Library and private collections (*The Sun,* 22 April 1941, p. 5). There were 144 artworks in the exhibition catalogue compiled by Sydney Ure Smith (Smith 1941, pp. 29–49). Smith was an artist and publisher who held leadership roles in the art world including president of the Society of Artists, trustee of the National Art Gallery of NSW, member of the Advisory Committee for Applied Art, and many others (Underhill 2024). In Hobart, Sizer said an interchange of art between Australia and the United States would help to remove wrong ideas, 'which in the case of Australia were gained to a considerable extent from Hollywood' (*The Mercury*, 20 February 1941, p. 4).

The artwork selected from the Royal Society of Tasmania Art Collection was Francis Guillemard Simpkinson de Wesselow's watercolour painting of *Kangaroo Bay, Hobart, 1846*, which became artwork number 26 in the exhibition catalogue (Smith 1941, p. 31; pl. 1). Smith observed that de Wesselow produced some of the best drawings and watercolours of Hobart, describing his work as excellent (Smith 1941, p. 20). Noted watercolourist Max Angus commented on this particular painting, in connection with de Wesselow's frequent painting excursions with fellow artist John Skinner Prout:

> *On 17 October 1846 they sat together at Kangaroo Bay, near Hobart Town, to each produce a watercolour of the first rank, full of light and atmosphere, the deft brushwork, sure draughtsmanship and sparkling light in one being almost indistinguishable from those qualities in the other.* (Angus 1984, p. 58)

This painting clearly has great appeal, as Professor Ross Large AO, Chair of the RST Art Committee, noted: 'The Simpkinson de Wesselow selected for the 1941 exhibition is my favourite from the Royal Society of Tasmania collection of over 200 de Wesselow watercolours. It depicts the Kangaroo Bay shoreline, a few boats at the old jetty, two houses on the Bluff and a magnificent rendition of

Plate 1 – Francis Guillemard Simpkinson de Wesselow's watercolour painting of *Kangaroo Bay, Hobart,* 1846. (Royal Society of Tasmania Art Collection)

Mount Wellington in the background.' (R Large, pers. comm., 2024).

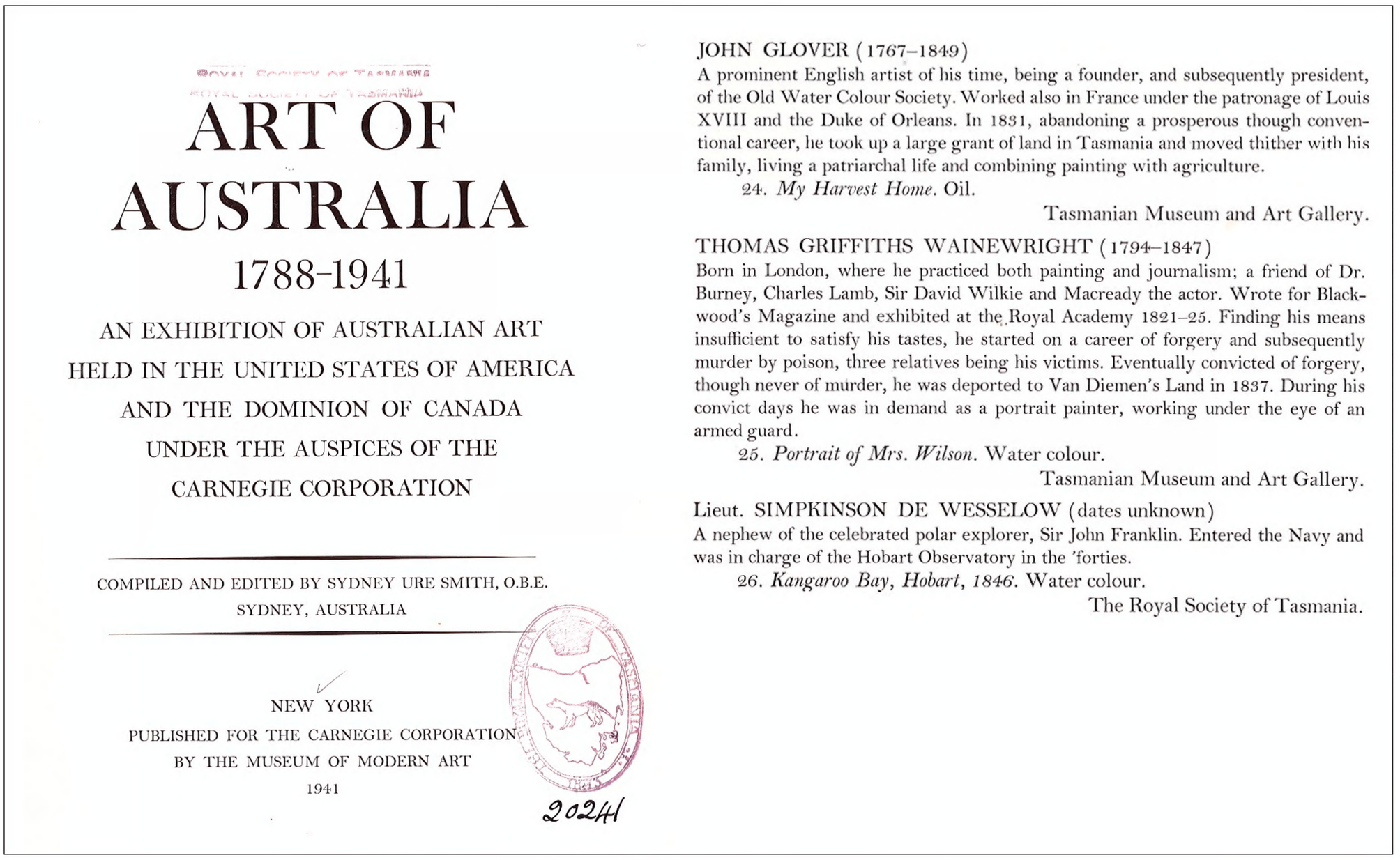
Francis Guillemard Simpkinson (1819–1906) was a naval lieutenant appointed in 1844 to the magnetic observatory in Hobart Town, where he was stationed for four years before returning to England. He was an accomplished artist who painted prolifically during his time in Tasmania, with some of his watercolours displayed at the first public exhibition of paintings in Australia held on 6 January 1845 at the Legislative Council chambers. He added 'de Wesselow' to his name later in life due to an inheritance in 1869 from the de Wesselow branch of the family (Hodgman 1967). In 1900 he gifted his large collection of fine colonial watercolours to the Royal Society of Tasmania, through the intervention of RST Vice-President Bishop HH Montgomery when the RST was focussed on gathering pictures, maps and documents important to Tasmanian cultural identity prior to Federation.

The paintings were packed in a zinc-lined case in England and sent by sea to Hobart Town, arriving unscathed and intact on the other side of the world. Max Angus notes: 'The generosity of this gift and the circumstances surrounding the making of it are among the most singular and interesting in the history of Australian colonial art' (Angus 1984, p. 16). At the monthly meeting of the RST in October 1900, the letter of donation from Simpkinson de Wesselow was read in full, and a vote of thanks moved to the donor of '…this priceless gift of works of art' was carried with acclamation (Royal Society of Tasmania 1900, p. x).

Two artworks selected from the separate Tasmanian Museum and Art Gallery Collection (TMAG) were: John Glover's *My Harvest Home,* artwork 24 in the exhibition catalogue, and Thomas Griffiths Wainewright's *Portrait of Mrs. Wilson*, artwork 25 (Smith 1941, pp. 30–31; pl. 2).

The timing of the exhibition seems extraordinary: it opened in the United States on 2 October 1941 (National Gallery of Art 1941a), two months before the Japanese bombing of Pearl Harbour that precipitated America entering World War II. The exhibition toured until 1945, travelling to 26 venues in the USA with a selection of the art also going to seven venues in Canada (Jordan 2013, p. 25; pl. 3). What occasioned this large and expensive undertaking in the middle of a world war? Was it prompted by a sudden desire of the American people to better acquaint themselves with Australian art? Or a thirst for inspirational 'cultural exchange in the midst of chaos', as Sizer opined? (*The Age*, 12 March 1941, p. 8).

The answer appears to be far more pragmatic. In an interview, Sizer commented directly on the world war in progress: 'Over in the States,' he said, 'we're realising that we have no friends any more except Great Britain — and it's high time we got together. British and Americans, we're all in this together, and we'll have to get out of it together'. (*The Herald*, 6 February 1941, p. 7). The



ROYAL SOCIETY OF TASMANIA

ART OF AUSTRALIA

1788–1941

AN EXHIBITION OF AUSTRALIAN ART
HELD IN THE UNITED STATES OF AMERICA
AND THE DOMINION OF CANADA
UNDER THE AUSPICES OF THE
CARNEGIE CORPORATION

COMPILED AND EDITED BY SYDNEY URE SMITH, O.B.E.
SYDNEY, AUSTRALIA

NEW YORK
PUBLISHED FOR THE CARNEGIE CORPORATION
BY THE MUSEUM OF MODERN ART
1941

ROYAL SOCIETY OF TASMANIA 1843

20241

JOHN GLOVER (1767–1849)
A prominent English artist of his time, being a founder, and subsequently president, of the Old Water Colour Society. Worked also in France under the patronage of Louis XVIII and the Duke of Orleans. In 1831, abandoning a prosperous though conventional career, he took up a large grant of land in Tasmania and moved thither with his family, living a patriarchal life and combining painting with agriculture.

24. *My Harvest Home*. Oil.

Tasmanian Museum and Art Gallery.

THOMAS GRIFFITHS WAINEWRIGHT (1794–1847)
Born in London, where he practiced both painting and journalism; a friend of Dr. Burney, Charles Lamb, Sir David Wilkie and Macready the actor. Wrote for Blackwood's Magazine and exhibited at the Royal Academy 1821–25. Finding his means insufficient to satisfy his tastes, he started on a career of forgery and subsequently murder by poison, three relatives being his victims. Eventually convicted of forgery, though never of murder, he was deported to Van Diemen's Land in 1837. During his convict days he was in demand as a portrait painter, working under the eye of an armed guard.

25. *Portrait of Mrs. Wilson*. Water colour.

Tasmanian Museum and Art Gallery.

Lieut. SIMPKINSON DE WESSELOW (dates unknown)
A nephew of the celebrated polar explorer, Sir John Franklin. Entered the Navy and was in charge of the Hobart Observatory in the 'forties.

26. *Kangaroo Bay, Hobart, 1846*. Water colour.

The Royal Society of Tasmania.

Plate 2 – Excerpt from the Art of Australia catalogue showing entries selected from the TMAG Art Collection and RST Art Collection.

exhibition was supported by the Australian Government 'as part of their soft power initiatives to encourage a closer US–Australia relationship' (Geissler 2019, p. 9). It generated goodwill for the Australian–American military alliance, and simultaneously gave exposure to Australian art in countries where it was formerly little known (Jordan 2013, p. 25). Indeed, an article by Theodore Sizer titled 'The Unknown Art of Australia' was published in October 1941 (*Sun News-Pictorial* 1941, p. 2).

The exhibition also had a large impact in Australia at the time. Sizer's opinions were much sought after in Australia and widely reported by the press (Jordan 2013, p. 26). In the Australian art world, the exhibition 'acted as a lightning rod for a conflict between modernists and anti-modernists that had been escalating since 1938' (Jordan 2013, p. 26).

It appears that Sizer endeavoured to avoid entanglement in the agitations and factions of the Australian art scene, concentrating on the key aims of the project. 'The aim is to make it historical,' he said. 'We want to know about Australian art, not Australian artists.' (*The Herald*, 6 February 1941, p. 7).

The National Gallery of Art (NGA) in Washington, where the exhibition opened, gave this overview: 'The exhibition presented a cycle, starting with the work of the aborigines, continuing with the dominating styles of 19th-century British art, and ending with the influence of aborigine work as a basis for a new outlook for the national art of Australia.' The NGA noted that the Washington exhibition also contained works from the collection of Ethel Marian (Maie) Casey, wife of the Australian Minister in Washington, RG Casey, and that 61 of the catalogued works toured to Canada (National Gallery of Art 1941b).

Australian diplomatic presence in the United States was very new. The world war with attendant threats in the Pacific led the Australian Government to the decision to establish a diplomatic legation in Washington, and Prime Minister Robert Menzies appointed RG Casey, a senior Cabinet colleague with previous diplomatic experience, to set this up (Lowe *et al.* 2016, p. 9). Minister and Mrs Casey were regarded as key players in the art project, and it is thought they were directed by the Australian Government to ensure both Australian and US needs were met (Ryan 2021). Mrs Casey, later Lady Casey, was an interesting character in her own right. She was herself an artist who attended the Westminster School of Art, London, continuing her studies in art on her return to Australia. She was a patron of the arts as well as a collector (National Portrait Gallery 2024), and she also found time to paint in the various countries in which she lived. Lady Casey was made a fellow of the Royal Society of Arts in 1979 and was appointed AC in 1982 (Langmore 2007).

The exhibition was notable for introducing Aboriginal art to America. Reviews were overwhelmingly positive, with the Aboriginal bark paintings often singled out for comment. For Theodore Sizer, the bark paintings were the highlight of the show because of their modernist appeal (Geissler 2019, p. 10). Significantly, several American art museums, including New York's Museum of Modern Art and the Metropolitan Museum of Art, purchased works from the exhibition (Jordan 2013, p. 25).

NATIONAL GALLERY OF ART
WASHINGTON, D. C.

FOR RELEASE
SUNDAY MORNING PAPERS
SEPTEMBER 28, 1941

EXHIBITION OF AUSTRALIAN ART

The first comprehensive exhibition of Australian Art to be shown in the United States will be held at the National Gallery of Art, from October 2nd to 26th, inclusive. The exhibition has been sent to this country by the Commonwealth of Australia, under the auspices of the Carnegie Corporation of New York. It will be circulated by the Museum of Modern Art of New York to museums throughout the United States, going from Washington to the Metropolitan Museum in New York.

The exhibition shows the development of Australian Art over a period of 150 years. It includes oil paintings, water colors, drawings, bark drawings and sculpture, and ranges from the art of Australian aborigines, prior to the arrival of the white man, to the most modern paintings of present-day artists.

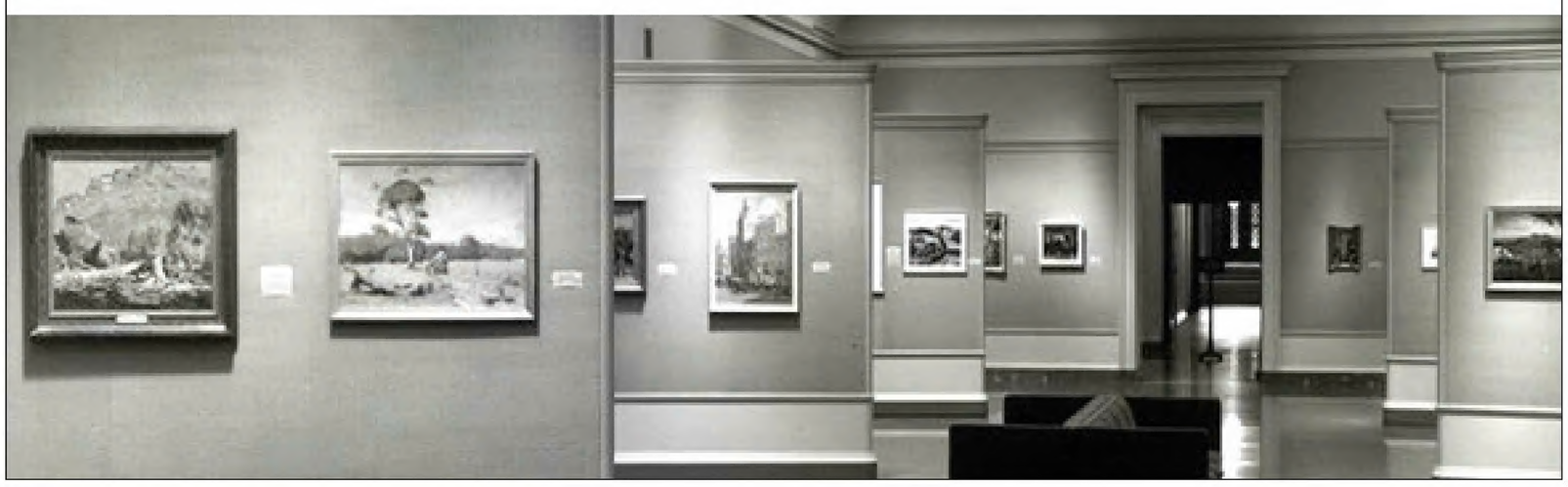


Plate 3 – Excerpt from the National Gallery of Art (1941a) press release and view of the artworks hanging in the exhibition. (source https://www.nga.gov/exhibitions/1941/art_australia.html)

The inclusion of a work from the Royal Society of Tasmania Art Collection in this Australia-wide selection of art speaks strongly to the standing of the Collection in the Australian art world in 1941, as well as the quality and interest of the chosen work by Simpkinson de Wesselow, of *Kangaroo Bay, Hobart*, painted in 1846. A copy of the exhibition catalogue is held in the Royal Society of Tasmania Library Collection housed in the Morris Miller Library, University of Tasmania, and makes very interesting reading.

ACKNOWLEDGEMENTS

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(accepted 11 July 2024)

PREDICTING SPATIAL VARIATION IN THE UPPER LIMIT OF TREES ON THE ALPINE MOUNTAINS OF LUTRUWITA/TASMANIA

by Jamie B Kirkpatrick

(with four figures and one table)

Kirkpatrick, JB (2024). Predicting spatial variation in the upper limit of trees on the alpine mountains of Lutruwita/Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 158: 7–15. ISSN: 0080-4703. School of Geography, Planning and Spatial Sciences, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia. Email: j.kirkpatrick@utas.edu.au

Climate change threatens obligate alpine plants with restricted distributions, especially where mountain peaks are not far above the climatic treeline (henceforth 'treeline'), as in Lutruwita/Tasmania where there are at least ten plant species that are only known to occur above the treeline and many more that only occur in alpine vegetation above and below the treeline. In a context of global warming, it is important to know the elevation of the treeline on each of the numerous alpine habitat islands in the state. Using the satellite image and contour layers in LISTmap, the highest elevation of trees on 49 alpine islands that had peaks above their treeline was determined. I then derived a predictive equation that explained 80.1% of the variance in this dataset and applied it to 141 alpine peaks. This analysis indicated that there were ten peaks on which the modelled treeline was more than 250 m elevation below the summit and 12 peaks on which the modelled treeline was more than 125 m in elevation above the summit. These results indicate that species extinctions in the alpine zone may not be imminent but are possible, especially for the eight Tasmanian endemics that are only known from above the treeline. Modelling of alpine lower limits and of the environmental ranges of the potentially threatened species is desirable.
Key Words: alpine, climate change, climatic treeline, Lutruwita, Tasmania.

INTRODUCTION

Climate change threatens obligate alpine plants with restricted distributions, especially where mountain peaks are not far above the climatic treeline (Dirnbock *et al.* 2011). Styger and Balmer (2009) suggest that the climatic treeline (henceforth 'treeline') in Lutruwita/Tasmania could be 250 m higher than at present by the year 2100. They assumed a 1.5°C rise in temperature and a 0.6°C environmental lapse rate. The former assumption now appears optimistic. On the other hand, there may be consequences of climate change that counteract the effects of sea level warming on the treeline. The best documented of these effects relates to increases in wind speed that have resulted from a steepening pressure gradient over Lutruwita/Tasmania. This increase has affected the steepness of environmental lapse rates, maintaining snow incidence at high elevations (Kirkpatrick *et al.* 2017). The Lutruwita/Tasmania treelines, where monitored over decades, have not changed (Harrison-Day *et al.* 2016, Balmer *et al.* 2021). This lack of response is no guarantee of a lack of change in the coming decades.

Prospective treeline change is potentially significant for the conservation of the Tasmanian biota, as there are at least ten vascular plants that do not occur below the climatic treeline in Lutruwita/Tasmania (Kirkpatrick 1986) of which eight are Tasmanian endemics. The alpine vegetation is recognised to have world heritage significance (Kirkpatrick *et al.* 1993, Balmer *et al.* 2004). It is therefore important to understand the variability of treeline altitude in relation to the altitude of the highest peak in the alpine habitat islands of Lutruwita/Tasmania.

Alpine vegetation in Lutruwita/Tasmania occurs as an archipelago of habitat islands (Kirkpatrick 1997). The treeless vegetation that occurs up to 300 m below the climatic treeline is floristically and structurally highly similar to that above the treeline, so the convention, followed herein, has been to include it as part of the alpine zone (Kirkpatrick 1997), and to refer to the part of the alpine zone above the climatic treeline as 'true alpine'. The lower limit of the alpine vegetation below the treeline corresponds with the upper limit of lowland sedgeland and heath in which buttongrass *Gymnoschoenus sphaerocephalus* is usually prominent. This boundary is associated with a persistent temperature inversion (Kirkpatrick *et al.* 1996). On the more fertile eastern mountains, the transition from alpine vegetation below the climatic treeline to lowland treeless vegetation is associated with the transition from *Eucalyptus coccifera* subalpine forest and woodland to montane forest dominated variously by *E. delegatensis*, *E. rodwayi*, *E. pauciflora* and *E. dalrympleana*.

I made the earliest attempt to determine the spatial variability of treeline elevation in Lutruwita/Tasmania in Kirkpatrick (1982). I applied an environmental lapse rate of 0.65°C per 100 m elevation to the mean temperature of the warmest month data from climatic stations near Tasmanian alpine mountains and assumed that a mean temperature of the warmest month of 10°C corresponded with the treeline. Using this approach, the treeline varied between 746 m and 1418 m for climate stations, but the stations recording temperature were sparse over most of the range of alpine habitat islands. Global data led Paulsen and Korner (2014) to the more refined predictor of three

months with daily mean temperatures above 0.9°C and with an overall temperature mean in these months higher than 6.4°C.

The recording of temperature data on transects up kunanyi/Mt Wellington (Nunez & Colhoun 1986) and up Mt Sprent in the remote southwest (Kirkpatrick *et al.* 1996), indicated that neither a linear environmental lapse rate nor a spatially constant environmental lapse rate could be assumed. These uncertainties suggested that an alternative approach to determining the altitudes of treelines within Lutruwita/Tasmania was desirable.

A recent review of southern hemisphere treelines (Hansson *et al.* 2023, p. 6) stated that the Tasmanian treeline 'generally rises from the southeast to the northwest'. The treeline certainly rises with increasing solar radiation from the southeast to northwest of individual mountains, but not between mountains. Between mountains it rises from the southwest to the northeast (Kirkpatrick 1982) in response to increasing continentality of climate and latitude (Kirkpatrick & Fowler 1998). The strong role of the maritime-continental climate gradient in affecting treeline elevation has also been recently documented for Norway (Byrne *et al.* 2022).

In this paper, I used observations of maximum treeline elevation on a subset of mountains where the treeline was below the peak, to develop a predictive equation. I then applied this equation to all the alpine mountains of Lutruwita/Tasmania (fig. 1). These data will be used in later work to indicate the relative susceptibility of the species in their alpine vegetation to anthropogenically induced warming.

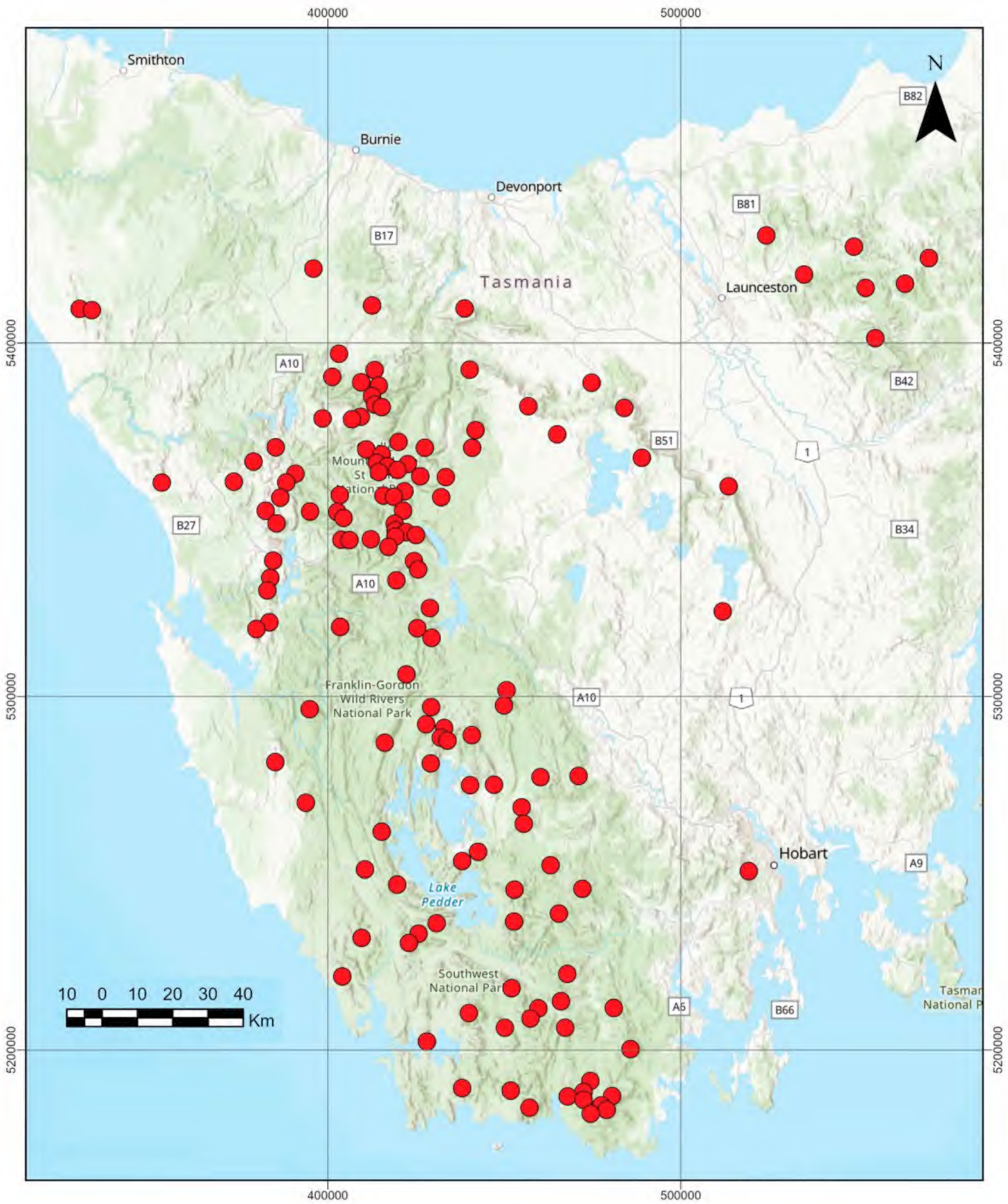

Figure 1 – Locations of the alpine peaks in table 1 (map created by Raiza Sartori).

METHODS

Data collection

Forty-nine mountains with alpine vegetation that I had previously ground-truthed and had an uppermost limit of trees below their peaks for apparently climatic reasons were selected in the first stage of data collection (fig. 2).

I examined the satellite images superimposed with the 10 m contour layer on LISTmap (Land Information Services Tasmania 2024) for each of these 49 mountains. I systematically searched for the highest altitude unambiguous trees, progressively following around individual contours, moving upward if trees were perceived above a contour. Places where the images were distorted in the rectification process were not included. When I found the highest tree, I recorded the nearest 10 m contour value. Trees were identified by their shadows, colour and canopy characteristics. The altitude of the peak was also recorded, mostly by reference to spot heights in topographic maps, but, for those without spot heights, in reference to the 10 m contours. The location of the peak was recorded in GDA94 MGA55.

I used the measurement tool in LISTmap to determine distances (km) of each peak to high energy coasts to the southwest, west and northwest, to indicate 'maritimeness' of climate, as most weather comes from these directions. Estuaries, such as Macquarie Harbour and the Tamar, were regarded to have low energy coasts. I recorded the dominant type of rock on each mountain in three classes (quartzite or quartzitic conglomerate; dolerite; and rocks of intermediate fertility, which were mostly sedimentary rocks in the Parmeener Supergroup).

I collected all the above data except the altitude of treeline from 92 other mountains that I knew supported alpine vegetation from my fieldwork, the literature or that I determined to have alpine vegetation from the satellite images. The resolution of these images is such that it is possible to discern buttongrass *Gymnoschoenus sphaerocephalus* hummock sedgeland from treeless vegetation lacking these hummocks. If such vegetation was above the hummock sedgeland and extended to the peak, it was assumed to be alpine.

Data analysis

I used the Best Subsets routine in Minitab21 to produce the best two multiple regression equations for each potential number of variables explaining treeline (m). These variables were: eastings (AGD94 MGA55); northings (AGD94 MGA55); distance to coast to the southwest (km); distance to coast to the west (km), distance to the coast to the northwest (km); minimum of these three distances to coast (km); mean of the three distances to coast (km). The best model, with a Mallows CP of 4.5, and an r^2 of 76.4 %, incorporated mean distance to coast, northings and distance to coast to the west. Mean distance to coast was the most explanatory single predictor linear relationship ($r^2 = 67.2$ %). Examination of the graph of this relationship indicated that it was quadratic, confirmed by later analyses ($r^2 = 76.9$ %). The residuals from this quadratic relationship were related to each of the remaining predictor variables, with only northings having a Pearson's correlation coefficient with $P < 0.05$. A linear regression was the best fit with the residuals. The residuals from the two variable model explaining treeline (incorporating the quadratic relationship with distance from coast and the linear relationship of northings with its residuals) were related to geological type using one-way ANOVA and to the remaining variables using the Pearson's correlation coefficient. There were no variables with a $P < 0.05$ and no indication in graphs that any polynomial fit would result in rejection of the null hypothesis. The two variable

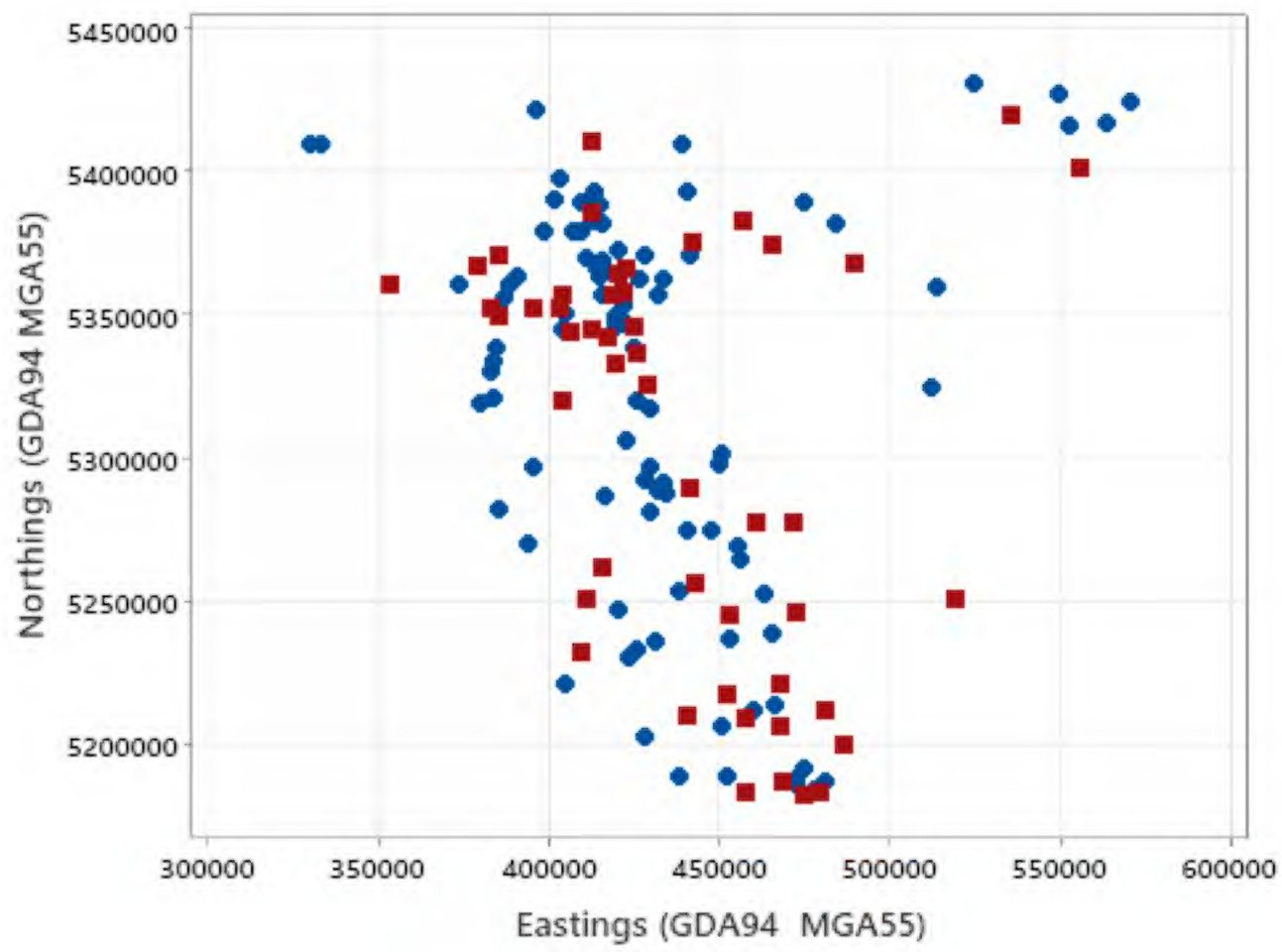

Figure 2 – Locations of the 141 peaks, showing the 49 peaks used for modelling (red squares) and the remaining peaks (blue diamonds).

model was accepted and applied to the full set of peaks. The elevation of the modelled treeline was then subtracted from the elevation of the individual peaks.

RESULTS

The most explanatory equation (r^2 = 80.1 %, fig. 3) to predict the treeline (m) incorporated mean distance from the coast (km) and northings (AGD94 MGA55):

*Treeline = (790.4 + 6.592 * mean distance - 0.02039 * mean distance²) + (-1597 + 0.000301*northings)*

There were many alpine peaks that were 125 m or less below the modelled treeline, but only a few that exceeded this deficit (fig. 4, table 1). Table Mountain was the extreme case at 257 m. The other alpine mountains with peaks more than 125 m below the modelled treeline were Mt Maurice (235 m), Mt Lee (229 m), Jubilee Range (211 m), The Needles (191 m), Mt Lewis (186 m), Mt Edith (174 m), Sentinel Range (170 m), Mt Arthur (169 m), Mt Norfolk (160 m), Granite Tor (144 m) and Mt Curly (132 m).

There were many mountains that were up to 225 m above the modelled alpine treeline (fig. 4, table 1). The extreme was Mt Ossa (366 m), followed by Eldon Peak (313 m), Mt Pelion West (310 m), Frenchmans Cap (304 m), Cradle Mt (299 m), Du Cane Range (279 m), Mt Thetis (263 m), Mt Anne (262 m), Pindars Peak (249 m), Mt Olympus (245 m), Mt Gell (245 m) and Ben Lomond (232 m).

DISCUSSION

There were potential errors in the measurement of treeline elevation, some of which were unavoidable. As the elevation of the treeline relates to summer heat (Paulsen & Korner 2014), the combinations of slope and aspect that orthogonally receive radiation in summer will have trees at higher elevation than other combinations. North-facing slopes could be expected to have the highest treelines if the slopes are appropriate, which is not necessarily the case. Also, many Tasmanian mountains have cliffs or extensive unvegetated block streams to the north, resulting in the highest elevation trees being on gentler, less rocky, slopes on other aspects. The quartzite mountains near the coast in the far southwest tend to only have trees on their south-facing slopes. These mountains have high negative residuals in the model (fig. 3, table 1). Some of the mountains selected to formulate the predictive equation may have had potential treelines above their peaks, as indicated in table 1, because the treeline was depressed by other factors, such as extreme exposure to strong winds or frequent burning.

Despite the above limitations, the model has very high explanatory value, enabling the identification of relative susceptibility of alpine vegetation islands to future warming. It is likely to be more accurate than climatic formulae such as TREELIM (Byrne *et al*. 2022) because it is based on trees ground-truthed in the field. The analysis suggests that a 250 m rise in the treeline will not eliminate true alpine vegetation, which will survive on at least eight mountains, which cover the edaphic range from the quartzite Frenchmans Cap to the dolerite Mt Ossa. However, it could eliminate at least one of the ten true alpine obligate species of Kirkpatrick (1986), as *Veronica ciliolata* only occurs on Ben Lomond, a mountain with a 232 m gap between treeline and peak.

It also indicates that there are many mountains currently supporting alpine vegetation below the current climatic treeline that might struggle to do so in the 250 m rise scenario (fig. 4, table 1). Over most of the state, alpine vegetation extends 100–300 m in elevation below the treeline, where trees are excluded by poor drainage and/

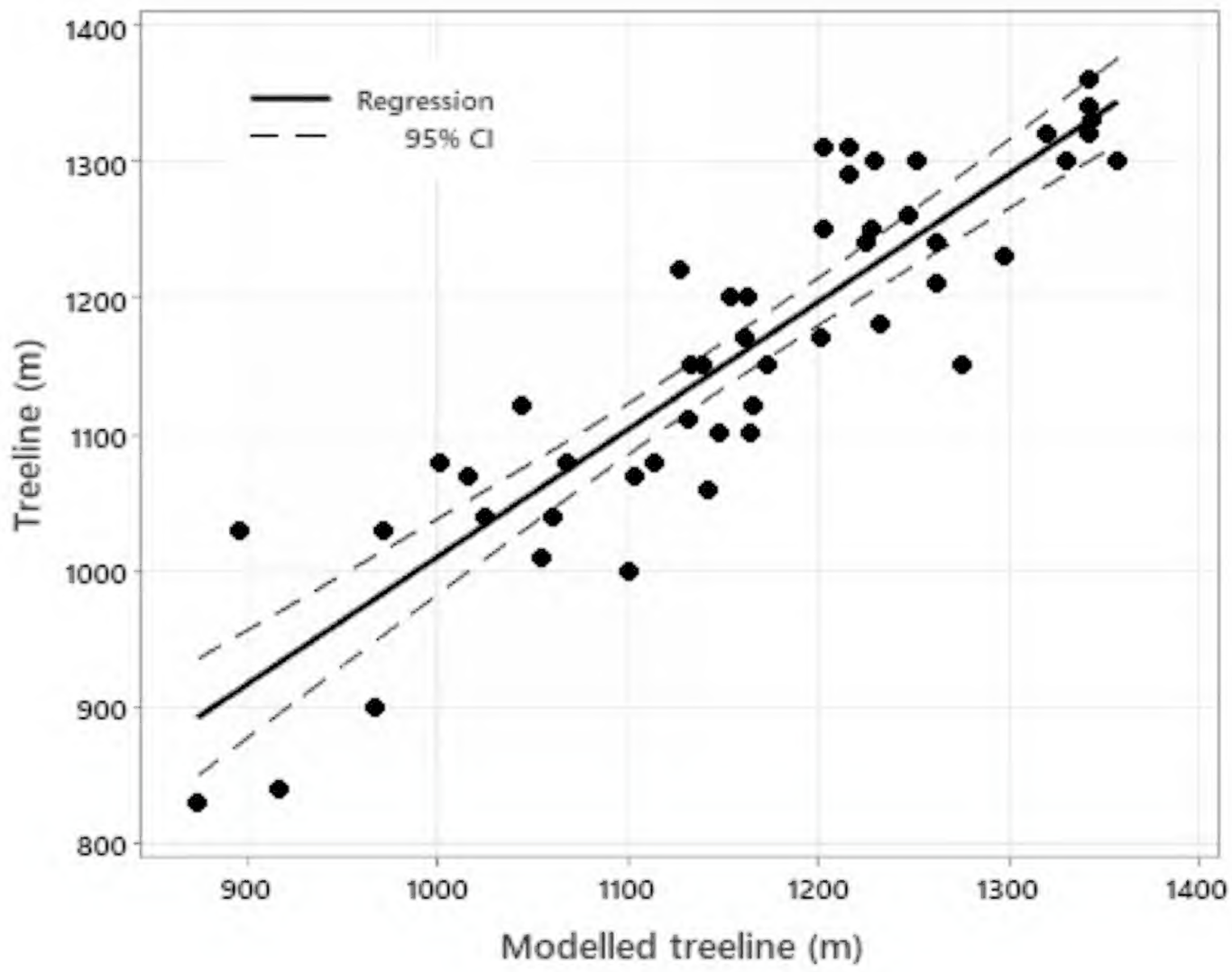

Figure 3 – The relationship between the modelled and observed treeline for 49 Tasmanian alpine areas.

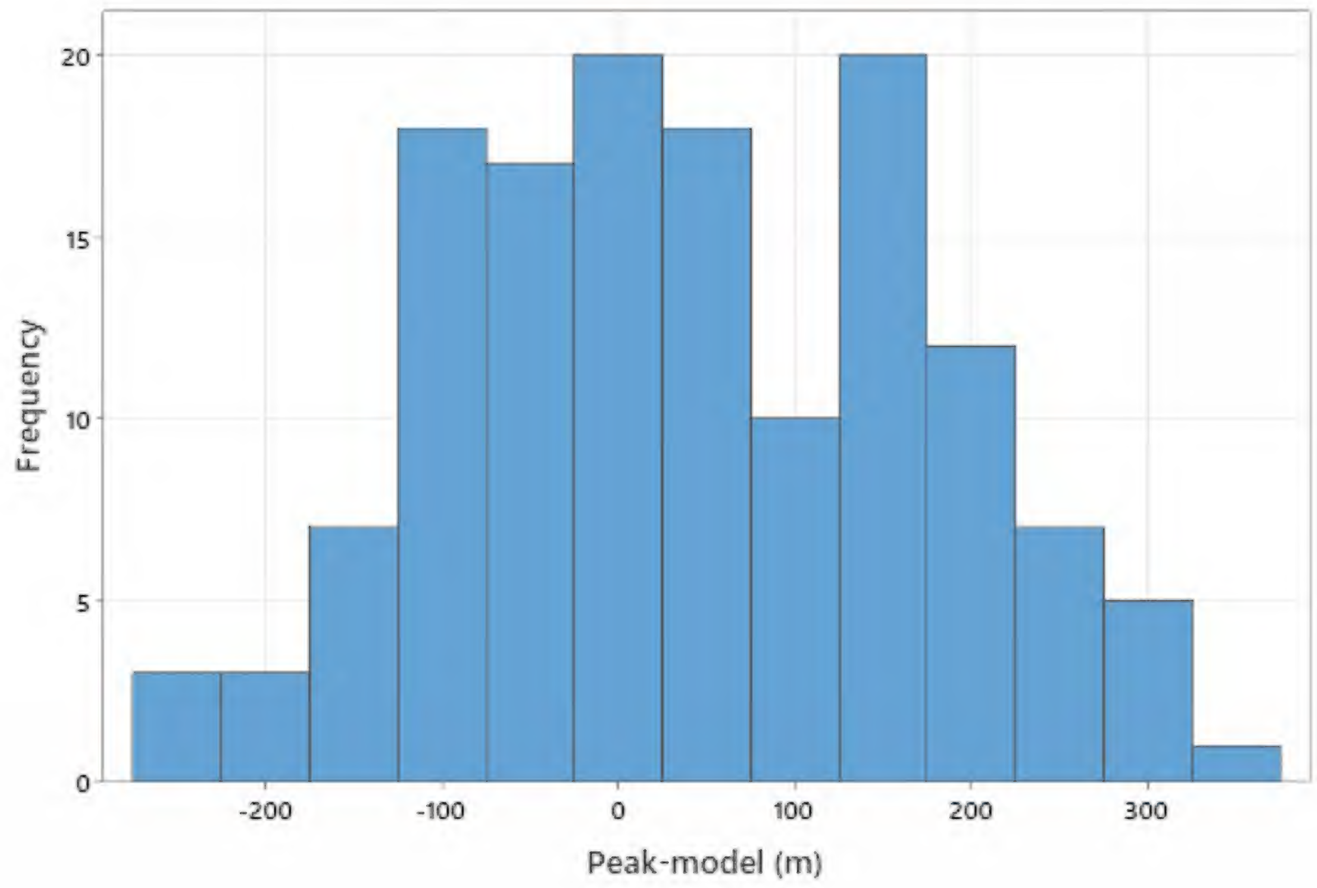

Figure 4 – The altitude between the modelled treeline and the peak for 141 peaks with alpine vegetation in Lutruwita/Tasmania.

or fire regimes. In the southwest on quartzite mountains the value is approximately 100 m, while on the Central Plateau it is approximately 300 m.

Further work is needed to build a model predicting this lower limit and to identify the downslope limits of taxa confined to the true alpine and/or alpine zones using records more recent than 1986 as well as earlier records.

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Table 1 – Location (GDA94 MGA55), measured treeline elevation (AT, m), modelled treeline elevation (MT, m), peak elevation (PE, m) and peak elevation-modelled treeline elevation (PE-MT, m) for Tasmanian mountains with alpine vegetation. *not part of the modelling set.

Mountain	Easting	Northing	AT	MT	PE	PE–MT
Mt Arthur	524288	5430386	*	1356.56	1188	–168.560
Mt Maurice	549070	5427238	*	1357.31	1122	–235.314
Mt Victoria	570337	5424020	*	1332.86	1213	–119.856
St Valentines	395967	5421065	*	1231.81	1107	–124.810
Mt Barrow	534861	5419425	1300	1356.34	1414	57.664
Mt Saddleback	563508	5416814	*	1346.47	1256	–90.465
Ben Nevis	552376	5415561	*	1349.66	1368	18.345
Black Bluff	412543	5410559	1150	1274.74	1339	64.256
Mt Roland	438709	5409745	*	1275.35	1234	–41.348
Mt Norfolk	329680	5409676	*	919.98	759	160.983
Mt Edith	333145	5409284	*	945.28	771	–174.278
Ben Lomond	555090	5401389	1360	1340.57	1573	232.429
Mt Beecroft	403103	5397007	*	1248.92	1140	–108.922
Western Bluff	440174	5392470	*	1283.89	1420	136.106
Mt Kate	413275	5392291	*	1258.70	1156	–102.700
Mt Remus	401207	5390375	*	1228.91	1110	–118.905
Brewery Knob	409424	5388937	*	1251.24	1203	–48.238
Quamby Bluff	474775	5388737	*	1324.19	1228	–96.192
Mt Campbell	414490	5387931	*	1260.98	1248	–12.975
Cradle Mountain	412576	5384992	1260	1246.26	1545	298.737
Little Mt Emmett	413387	5382628	*	1262.02	1250	–12.022
Ironstone Mt	456790	5382107	1330	1342.22	1444	101.780
Mt Emmett	415240	5381870	*	1250.98	1410	159.023
Drys Bluff	484046	5381660	*	1332.66	1330	–2.658
Un–named Mt4	409364	5379183	*	1242.59	1215	–27.594
Granite Tor	398476	5378633	*	1177.61	1034	–143.615
Mt Inglis	406783	5378473	*	1230.48	1281	50.525
Clumner Bluff	441875	5375372	1320	1318.27	1458	139.733
Wild Dog Tier	465032	5374195	1340	1341.21	1394	52.786
Mt Oakleigh	420002	5372014	*	1234.57	1286	51.435
Mt Murchison	385174	5370509	1000	1099.06	1278	178.939
Walls of Jerusalem	440879	5370370	*	1298.94	1499	200.065
Mt Pillinger	427496	5370349	*	1273.33	1270	–3.328
Mt Proteus	410860	5369837	*	1210.99	1152	–58.988
Mt Pelion West	415258	5368449	*	1249.70	1560	310.298
Sandbank Tier	488947	5367535	1320	1341.82	1401	59.183
Mt Read	378927	5366400	1040	1059.26	1123	63.741
Un–named Mt3	413796	5366127	*	1218.46	1211	–7.460
Pelion East	422622	5365719	1300	1328.89	1461	132.114
Mt Thetis	416976	5365109	*	1218.15	1482	263.846
Mt Ossa	419790	5364097	1300	1251.12	1617	365.883
Perrins Bluff	414376	5363456	*	1216.60	1420	203.401
Un–named Mt2	390841	5363049	*	1120.01	1026	–94.011

Table 1 cont.

Mountain	Easting	Northing	AT	MT	PE	PE–MT
Cathedral Mt	426167	5362335	*	1261.08	1387	125.922
Mt Ragoona	433409	5362072	*	1275.51	1350	74.488
Mt Dundas	373361	5360712	*	1002.31	1143	140.694
Mt Agnew	352909	5360535	830	872.86	848	–24.861
Sticht Range	388154	5360459	*	1082.48	1080	–2.479
Millers Bluff	513598	5359489	*	1338.31	1213	–125.307
Du Cane Range	421646	5358055	1300	1228.37	1507	278.630
Dome Hill	403412	5356962	1150	1132.09	1177	44.914
Macs Mt	415719	5356839	*	1213.54	1413	199.455
Walled Mt	418666	5356493	1310	1214.50	1431	216.497
Mtns of Jupiter	432093	5356401	*	1269.13	1326	56.870
Walford Peak	386569	5356223	*	1051.38	1009	–42.378
Mt Gould	421310	5352609	*	1220.64	1485	264.357
Tyndall Range	382348	5352536	1040	1023.88	1191	167.117
Eldon Peak	394974	5352354	1220	1126.57	1440	313.425
Eldon Bluff	402717	5352170	1170	1159.65	1361	201.353
Castle Mt	404419	5350563	*	1154.05	1208	53.947
Mt Sedgewick	385431	5348981	1120	1042.71	1146	103.289
Mt Manfred	418974	5348935	*	1210.10	1382	171.901
Mt Cuvier	419167	5346951	*	1210.57	1378	167.432
Mt Byron	422163	5346493	*	1214.65	1375	160.348
Mt Olympus	424982	5345663	1250	1226.63	1472	245.366
Coal Hill	419171	5345367	*	1201.43	1190	–11.430
Pyramid Mt	412186	5344550	1200	1161.14	1269	107.862
Camp/Last Hill	403870	5344406	*	1143.08	1172	28.918
Rocky Hill	406166	5344227	1150	1137.72	1194	56.281
Goulds Sugarloaf	417166	5342350	1250	1201.62	1425	223.379
Mt Owen	384563	5338420	*	1011.15	1145	133.849
Mt Hugel	424389	5338314	*	1240.63	1403	162.368
Mt Rufus	425560	5335993	1290	1215.64	1416	200.359
Mt Huxley	383692	5333604	*	997.63	925	–72.635
Mt Gell	419395	5332807	1310	1202.02	1447	244.983
Mt Jukes	382898	5329974	*	987.79	1169	181.213
King William I	428874	5325030	1240	1224.36	1324	99.645
Table Mt	511888	5324035	*	1326.81	1070	–256.813
Mt Darwin	383395	5321002	*	988.60	1033	44.398
Frenchmans Cap	403539	5319669	1060	1140.87	1445	304.126
Loddon Bluff	425401	5319353	*	1193.60	1220	26.400
Mt Sorell	379811	5319052	*	966.65	1143	176.351
King William II	429365	5316573	*	1203.54	1361	157.455
Algonkian Mt	422239	5306224	*	1155.82	1073	–82.819
Mt Shakespeare	450679	5301781	*	1247.85	1221	–26.852
Wylds Craig	449922	5297502	*	1239.86	1339	99.140
Innes High Rocky	429247	5296975	*	1169.84	1083	–86.842

Table 1 cont.

Mountain	Easting	Northing	AT	MT	PE	PE–MT
Elliot Range	394819	5296398	*	1026.88	911	–115.883
White Pyramid	427879	5292138	*	1173.03	1071	–102.025
Mt Curly	433001	5291111	*	1196.93	1065	–131.934
Denison Range	440753	5289064	1170	1200.49	1290	89.515
Unnamed Range	431992	5288383	*	1180.96	1078	–102.955
Pokana Peak	433848	5287471	*	1186.20	1127	–59.196
Prince of Wales	416069	5286913	*	1115.09	1069	–46.086
Mt Lee	385073	5281516	*	962.55	734	–228.545
The Pleiades	429205	5281148	*	1160.37	1082	–78.367
Mt Field East	471008	5277501	1240	1261.72	1274	12.276
Mt Field West	460270	5277219	1210	1260.94	1439	178.056
The Thumbs	447097	5274995	*	1191.03	1204	12.970
Clear Hill	440369	5274949	*	1185.68	1198	12.318
Mt Lewis	393724	5269898	*	983.66	798	–185.658
The Needles	454945	5268680	*	1223.30	1032	–191.296
Mt Mueller	455530	5264059	*	1219.19	1245	25.806
Mt Sprent	415230	5261799	1010	1054.31	1058	3.693
Mt Wedge	442561	5256103	1100	1163.33	1147	–16.327
Sentinel Range	438034	5253413	*	1143.60	974	–169.600
Jubilee Range	463137	5252260	*	1223.65	1013	–210.653
High Dome	410467	5251027	1200	1152.49	1366	213.515
kunanyi/Mt Wellington	519211	5250590	1230	1296.47	1271	–25.466
Double Peak	419708	5246799	*	1043.67	1061	17.333
Snowy Range	472178	5245576	1180	1230.93	1398	167.066
Mt Anne	452920	5245411	1150	1172.44	1435	262.558
Mt Weld	465526	5238637	*	1192.43	1344	151.574
Schnells Ridge	452739	5236374	*	1148.07	1087	–61.075
Folded Range	430775	5235819	*	1046.49	966	–80.487
Mt Maconochie	425657	5232893	*	1004.50	958	–46.497
Prosting Range	409531	5231699	840	916.47	894	–22.474
Greystone Bluff	423021	5230315	*	982.02	1019	36.982
Mt Picton	467798	5221496	1120	1164.14	1327	162.855
Mt Hean	404107	5220807	*	807.90	749	–58.903
Western Arthurs	452042	5217470	1070	1102.23	1160	57.771
South Picton Range	466043	5213759	*	1129.22	1082	–47.217
Hartz Peak	481078	5211896	1100	1147.72	1254	106.281
Mt Hopetoun	459645	5211721	*	1116.10	1087	–29.101
Mt Norold	439913	5210412	900	965.75	970	4.248
Eastern Arthurs	457388	5208973	1080	1066.51	1225	158.490
Mt Pollux	450169	5206359	*	1004.65	916	–88.654
Mt Bobs	467292	5206308	1080	1113.20	1111	–2.196
Mt Rugby	428026	5202374	*	875.26	773	–102.260
Adamsons Peak	485790	5200258	1110	1130.03	1225	94.972
Mt Bisdee	474405	5191259	*	1034.59	1005	–29.594

Table 1 cont.

Mountain	Easting	Northing	AT	MT	PE	PE–MT
Mt Counsel	438113	5189185	*	880.95	802	–78.952
Mt Louisa	451804	5188489	*	921.91	931	9.094
Mt Victoria Cross	472508	5188155	*	1026.01	1120	93.985
Moonlight Ridge	480539	5187017	*	1071.24	1036	–35.245
Precipitous Bluff	467961	5186883	1030	970.64	1145	174.358
Mt Wylly	472448	5185921	*	1014.45	1110	95.551
Maxwell Ridge	477513	5184358	*	1050.40	1060	9.597
Ironbound Range	457180	5183595	1030	894.49	1061	166.508
Mt La Perouse	479056	5182996	1070	1015.14	1161	145.862
Pindars Peak	474491	5182002	1080	1000.55	1250	249.452

BOTANICAL RENDERINGS: THE UNIQUE REPRESENTATIONS OF NATIVE PLANTS IN ST JOHN'S CHURCH, LAUNCESTON

by Eric Ratcliff

(with eight plates)

Ratcliff, E (2024). Botanical renderings: the unique representations of native plants in St John's Church, Launceston. *Papers and Proceedings of the Royal Society of Tasmania.* 158: 17–24. ISSN: 0080–4703. Albion House, 153 & 155 George Street, Launceston, Tasmania 7250, Australia. Email: eric.ratcliff.albion2@gmail.com

In St John's Church in Launceston, Tasmania, there are remarkably accomplished representations of Tasmanian native plants, formed in masonry, all but one decorating capitals consisting of coloured concrete. They were designed by the architect Alexander North, and, with the exception of one carved in sandstone, were executed by Gordon Cumming in 1938–1939. Possible influences on these designs, and the choices of subject, are considered. This paper examines a late and unusual manifestation of these, executed by hand in the difficult medium of coloured Portland cement render, and to a remarkable extent, overcoming the problems of expressing fine detail and colour contrast in such a material. The plants represented are native to Australia, half of them endemic to Tasmania, so their representations are mostly without any close precedent, and in this form, unique.

Key Words: Tasmanian native plants, carving, modelling, Portland cement render, Federation style, Neo-Gothic, Art Nouveau, Celtic patterns.

The ubiquity of leafy vegetation and flowering plants both explains and questions the innumerable representations of them in the visual arts: in meticulous detail in botanical drawings and prints, in the more superficial and aesthetic preservation of the ephemeral in painted flower-pieces, and in abstracted and stylised form in every medium from wallpaper to architectural sculpture. In that last category, there is a long history of the decoration of religious buildings with plant forms, probably pre-dating the *anthemion* (a putative honeysuckle) of Ancient Greece, the *acanthus* of the Corinthian capital and its innumerable corruptions in the Middle Ages, the apotropaic 'green man', the stiff-leaf, the ball-flower and the crocket of Gothic architecture, the *rinceau* of Renaissance decoration, and the return of stylised or attempted realism in the latter half of the nineteenth century.

St John's Church in Launceston was built for one of the earliest Church of England parishes in the Australian colonies. The first entries in the Parish Register date from 1811, and the parish was formally established in 1819. Construction began in 1824, and the building opened for worship at the end of the following year, although the tower was not completed until 1829. The building was of brick, stuccoed without and plastered within, the congregational space approximately square in plan but with a shallow bow at the eastward end behind the altar, and a pair of vestries and a pair of stairs to the gallery flanking the tower at the westward end. Externally, the style was *Gothick* in the eighteenth-century sense, and essentially Georgian within. Changing liturgical requirements led to the addition of a chancel with Gothic Revival features in 1866.

Before the end of the nineteenth century, a larger building was needed. The parishioners sought a design for the replacement of the old church as early as 1892, but building did not commence until 1901. To the east of the old building, a massive polygonal chancel, a pair of transepts, a side chapel and an organ loft above a choir vestry began to rise after an ambitious design by Alexander North (1858–1945). They were built of red brick and yellow sandstone, and stand on dolerite basements resting on concrete, the last an innovation that was just beginning to emerge from the industrial realm. Because of financial constraints, building proceeded gradually, and with successive modifications to the design, until 1927. The crossing between the transepts was roofed with a dome, the chancel and transepts with vaulting, all built with reinforced concrete. North's partner, A. Harold Masters (1874–1951) had a pioneering interest in the domestic use of 'camerated concrete' and several important Launceston buildings resulted from their collaboration. The whole of the new work was achieved without disturbing the older buildings; the dome hovered above the much lower 1866 chancel until the entire east end of the church was demolished to open into the new spaces. The rest of the old building continued as the nave, totally different in style and scale, and North was asked to provide an economical design that would enable the building of a replacement to harmonise with his eastward achievements.

North decided to retain much of the old side walls, but to breach them to allow for arcades giving on to narrow side aisles, locally referred to as *ambulatories,* and to encase the remnants with new masonry and surmount them with a tall clerestory to more than double the height of the space. This last was designed in a Neo-Gothic style, with the use of concrete coloured to look like sandstone to match the natural stone of the earlier work. The building was essentially completed in 1938 (plate 1).

North's association with the Arts and Crafts Society of Northern Tasmania was notable (Miley 1987, pp. 33, 55), and some of his work suggests influences from the parent

Plate 1 – St John's Church Launceston 1954. (image AB713-1-4335 Libraries Tasmania, Open Access)

Plate 2 – 1939 ca - View into north ambulatory alongside the then new nave. The old colonial walls were incorporated into the walls through which the archways pass. Note that the decorative work on the pillar capitals is completed in this photograph. (copyright All Saints Anglican Network)

guilds in England. However, the principal subject of this paper is separated by both date and artifice from precepts most characteristic of the Arts and Crafts Movement. There was a fashion for applying motifs from native flora that reached its height among designers in Australia in the decades surrounding the turn of the nineteenth century; the works under consideration here appeared much later.

Alexander North's large interventions at St John's are in many ways unique, with features from the Gothic Revival, from Byzantium by way of Tuscany, and John Francis Bentley's Roman Catholic Cathedral at Westminster, from the Antipodean Edwardian styles now labelled 'Federation', and the Neo-Gothic of the years between the world wars. The westward end including the tower remains colonial and Gothick, venerable by Australasian standards, a familiar anachronism, part of the uniqueness of a most peculiar and historic building.

It is the archways between the remnants of the old walls that are the focus of this paper (plate 2). The pointed brick arches spring from sandstone-coloured concrete capitals that spread from half-columns formed by rendering around the cut away ends of the 1825 brickwork. The capitals are rectangular in plan, the shafts of the columns plain half-cylinders; it is North's treatments of the transitions from round to square that are of particular interest.

Alexander North was born in Yorkshire and educated in the north of England and in London, where in 1883 he was awarded the gold medal in a national competition for students at schools of art (Maidment 2012). The set subject for the competition was a design for a cathedral suitable for a British colony (*Launceston Examiner*, 16 June 1886, p. 2), and North's winning entry has many resemblances to the design he eventually produced for St John's. North emigrated for health reasons in 1884 and was employed in Hobart in the Public Works Department. There, he designed the Post Office for Launceston in a style described at the time as 'Queen Anne', and in 1885 he moved to Launceston to supervise its construction and remained to engage in private practice. The carved sandstone decorations on the Post Office include representations of birds and foliage considered emblematic of Britain and Australia. North was a major exponent of the Arts and Crafts Movement in Australia and developed an interest in botany as well as a professional interest in native timber. He presented and published papers on the ferns of Tasmania (North 1891), and on the economic uses of Tasmanian forest timbers (North 1904).

One of the churchwardens during the 1901–1911 building campaign, and the principal donor of the rose window in the north transept, was the draper, Walter Perrin. Perrin died in 1915 and is commemorated in a mural monument in the south transept (Gill 1988). The marble tablet is surrounded by carved stonework including naturalistic representation of an Australian native plant, *Kennedia prostrata,* the 'running postman' (plate 3). The crisp carving, interpreting North's design, was probably executed by the sculptor and woodcarver Hugh Cunningham (1858–1942) but could also have been by the Devonian-born monumental mason, Sylvanus Wilmot (1857–1926), who had trained in England and Italy (Cyclopedia of Tasmania 1900). The choice of *Kennedia* is intriguing. The prostrate plant with its red flowers with yellow centres spreads profusely on the floor of open sclerophyll forest in the hills to the west of Launceston that are divided by the gorge of the South Esk River, so at the time may have been a familiar favourite of the man commemorated.

The 'running postman' was to appear again on one of the capitals of the nave arcade, but this time it was modelled or carved in cement render, one of a remarkable set of decorations designed by Alexander North and executed by Gordon Cumming (1894–1972). The arcades of the nave are each of three arches, so there are twelve half-columns with decorated capitals, all of them different in design, although one species appears twice.

Plate 3 – The Walter Perrin monument in the south transept chapel, decorated with *Kennedia prostrata* carved in sandstone, probably by Hugh Cunningham in about 1916. (Author's photograph 2020)

On the south side, from the west, there are representations of native laurel *Anopterus glandulosus,* Tasmanian waratah *Telopea truncata,* Macquarie vine *Muhlenbeckia gunnii,* blackwood *Acacia melanoxylon, Kennedia prostrata,* and silver banksia *Banksia marginata.* Two of the six species are endemic to Tasmania. On the north side, there are Tasmanian blue gum *Eucalyptus globulus,* native laurel in what is probably its earlier presentation, black peppermint *Eucalyptus amygdalina,* native fuchsia *Correa reflexa,* Christmas bells *Blandfordia punicea* and celery-top pine *Phyllocladus aspleniifolius*; four of the six species are endemic to Tasmania. Gordon Cumming was photographed at work on the *Anopterus* in the north arcade (plate 4a). He was in motion, so slightly blurred, and it is tempting to suspect that this may have been the earliest of the capitals he worked on.

William Gordon Cumming was a skilled woodcarver and cabinetmaker who also developed a facility in working with concrete. His mentor had been the sculptor and woodcarver, Hugh Cunningham, who taught at the Launceston Technical College and was responsible for the stone carving in the 1901–1927 work at St John's. Other examples of Cumming's work in concrete are the Tasmanian Coats of Arms on the Supreme Court in Cameron Street, Launceston. His woodworking skill is seen at its height in the city Coat of Arms in the Launceston Town Hall, and the Gothic canopy over the baptismal font at Holy Trinity Church in Launceston. He taught woodwork to generations of schoolchildren, including the present author, and innumerable others who wanted to learn to carve. The lessons were held in his workshop at Trotsford

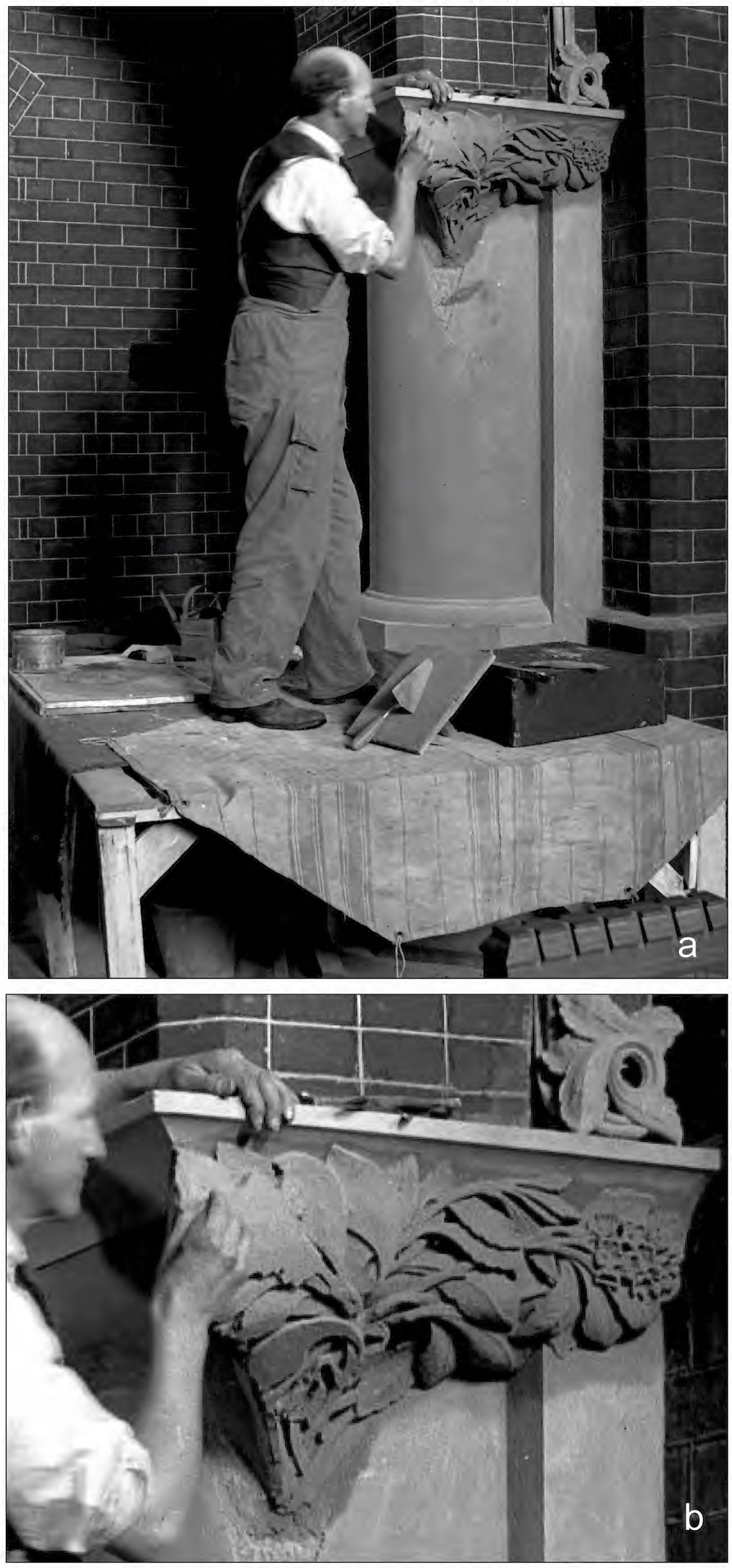

Plate 4 – (4a) Gordon Cumming at work on a capital in the north arcade of St John's Church in 1939, displaying Tasmanian laurel *Anopterus glandulosa,* and (4b), closeup showing Cumming's craft in fine detail. (copyright All Saints Anglican Network)

Crescent, East Launceston, decorated internally with design drawings and pieces of his carving that had failed to meet his exacting standards.

Cumming's own designs have been described as 'frequently reflecting his love of nature' (Miley 1987, p. 53), but it is clear the St John's capitals were designed by Alexander North. Although the drawings for them have not been located, related drawings that were not used, some from a private collection and some held by the Queen Victoria Museum and Art Gallery, dated 1934, 1938 and 1939, were exhibited there in 1987 (Miley 1987, p. 62). Cumming was well-suited to the

task of interpreting actual plants, and it may be that he had specimens or photographs to refer to as well as the architect's drawings. The freedom and elegance of the work suggests that Cumming was given a largely free hand, and the results must be regarded as a joint achievement by both architect and carver (plate 4b).

Fine modelling in cement render is not a simple matter. The material must be in an early stage of setting, but not set. It had to be coloured to match as closely as possible the render of the columns and the abaci, and the closeness of the match would not be apparent until the work was dry. The material must be wet enough when applied to adhere to the supporting structure, but not so wet as to drop or dribble away. Any competent renderer could meet those requirements, but detailed sculpture in wet render is another matter. If trowelled repeatedly to make a small form, the material is likely to soften and deform and even to liquefy, so most of the work entailed actual carving of the firm but still soft material, and pieces that broke away or were damaged could not readily be made good.

The mass of material applied had to approximate the amount that could be finished in a working session, and any unfinished render had to be scraped away before it set. Cumming's task had resemblances to that of painters of fresco, when the colour was applied to fresh plaster, and any of that left unpainted at the end of the day had to be removed.

This analogy was noted in France after 1926, when Carlo Sarrabezolles (1888–1971) was credited with the invention of the technique that was to be described as *sculpture à la fresque* (Bréon *et al.* 2013). It would be of interest to know whether North or Cumming were aware of this, or whether they developed the method independently.

The stems of the plants emerge from abstract devices on the smooth shafts, mostly producing combinations of the real and the unreal of a kind once familiar in Art Nouveau designs made four decades earlier. Most of the devices are reminiscent of Celtic knot-work, some sinuous and some more geometrical, and some of imitative ribbon-work. Leaf-forms are artistically arranged in such a way as to suggest their natural habit although not necessarily imitating it. Flowers are directed towards the corners wherever possible.

All of North's selections are botanically recognisable, but they vary in the degree of realism applied. Obviously fluffy flowers like those on banksias, eucalypts or blackwood do not lend themselves to illustration in stone or concrete, but in three cases, the attempt was made, without conspicuous success. In the case of the *Kennedia*, the pea-flowers are enlarged, strongly abstracted and unrealistically arranged, the vivid colour contrast suggested in reverse by deep dark hollows at the centres.

The continuous combination of realistic depiction, stylisation and abstraction is one of the characteristics of Art Nouveau style, but in the capitals, realism prevails, although the influence of the style is discernible in the curving of what in nature would usually be straighter. Many of the abstract parts of the designs owe much to Celtic patterns, particularly from illuminated manuscripts such as the *Book of Kells* which had been widely published by the time North made his drawings (Sullivan 1920). Less comprehensive and detailed sources had been readily available in the nineteenth century in Owen Jones' *Grammar of Ornament* and Richard Glazier's *Manual of Historic Ornament* (Jones 1859, Glazier 1899), but the detail suggests the later source.

All the designs, with one exception, are constrained by the coving under the plain abaci of the capitals, but the motifs are continued above these in the terminals of the hood-mouldings surrounding the brick arches. The one exception is the marvellous representation of the *Correa reflexa,* in which some of the flowers are made to dangle over the edge of the abacus like the tassel of an academic's headgear, so convincingly that one almost expects them to move in a draught. In nearly every case, the emergence of the stems from an abstract device a short way down the shaft of the half-column, overcomes the design problem of their growth from a plain half-cylinder with no other decoration. The rendered columns are left plain, a 'truthful' expression of the material, with no attempt made to pretend that it is stone, such as by engraving false mortar-joints. North had published twice on *The Truthful Treatment of Brickwork* (North 1882, 1892), the second time at the height of the fashion for tuck-pointing, but with the bricks affordable in 1936 he resorted to this untruthful technique, and undoubtedly had reservations about being forced to use yellow concrete in place of sandstone. His 1885 Launceston Post Office has tuck-pointed brickwork, and sandstone dressings, but North sought to avoid application of the former when he could.

BOTANICAL CAPITALS

The twelve capitals described here were all carved in 1938 and 1939, when the new nave was already in use. They are considered in the order in which they are placed, starting from the westward end of the arcade. The visitor will find the first six on the north side, and the second six on the south.

Anopterus glandulosus Tasmanian laurel is endemic to Tasmania, a tall understorey shrub growing in rainforests. It has stiff leaves and fleshy white flowers that lend themselves to sculptural treatment. The stems emerge from angular ribbon-work that is characteristically Art Nouveau in derivation (plate 5).

Telopea truncata Tasmanian waratah is also endemic to Tasmania and grows in high rainfall and mountain forests as an understorey shrub. The stiff foliage is rendered naturalistically, but the wide flower heads, usually scarlet but uncommonly yellow, and from 5–8 cm across with multiple florets with long upcurving stiles, have had to be represented in bas-relief, as if pressed flat, as a reference specimen may have been.

Muehlenbeckia gunnii is prevalent in high rainfall forests throughout southeastern Australia, but it derives its generic name from the botanist, Ronald Campbell Gunn (1808–1881), an early Secretary of the Royal Society of Tasmania, and its popular name, Macquarie vine, not directly from the Governor, but from Macquarie Harbour in western Tasmania, from the time of the penal settlement

Plate 5 – St John's capital featuring Tasmanian laurel *Anopterus glandulosa.* (Author's photograph 2020)

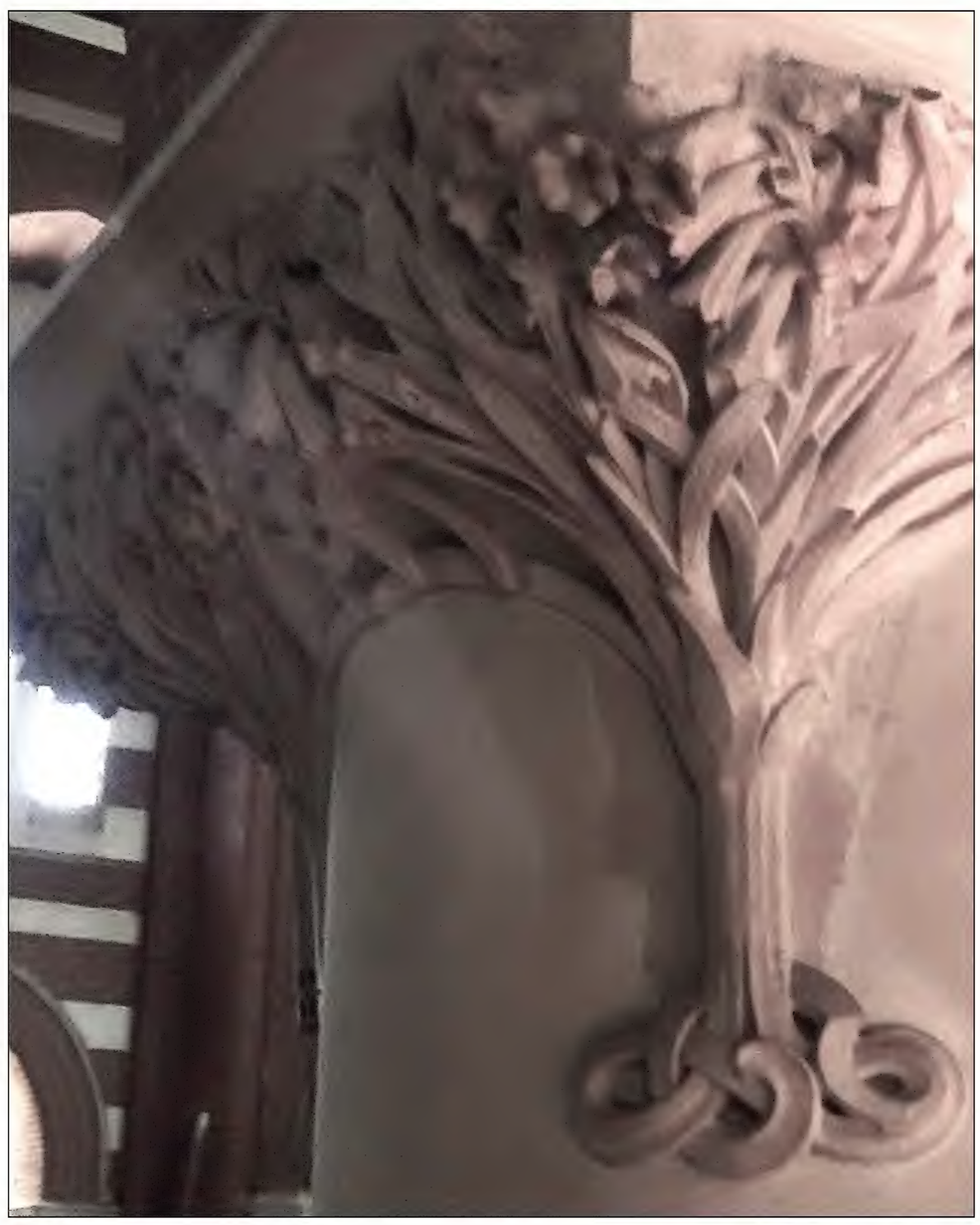

Plate 6 – St John's capital featuring Christmas bells *Blandfordia punicea.* (Author's photograph 2020)

there. North's design expresses its habit as a vine by the flowing lines of the stems, emphasises the hastate form of the petiolate leaves, and enlarges the flowers.

Acacia melanoxylon blackwood is a tree of economic importance that grows throughout southeastern Australia and can reach a height of about thirty metres. The timber has been highly valued, especially for furniture and panelling. The wattle-like juvenile leaves are transient, and the adult foliage consists of flat phyllodes (expanded petioles) so that they are parallel-veined. North's design curves the phyllodes more than is common in nature. The flowers are fluffy globes, not readily rendered in sculpture, so here they look more like raspberries.

Kennedia prostrata runs on dry forest floors throughout Australia, with orbicular leaves and crimson pea-like flowers with yellow centres. The common name, running postman, is attributed to the rapid spread of the plant, particularly after burning, and the red jackets formerly worn by colonial postmen. Hugh Cunningham's sandstone carving around the Perrin monument (plate 4) shows the plant in natural form, but in the capital, the flowers have been greatly enlarged and stylised, and the colour contrast is suggested in the negative by deep shadow. The straggling stems emerge from braided Celtic ribbon-work.

Banksia marginata silver banksia occurs as a shrub or small tree throughout southeastern Australia, with narrow leaves and 'brush' flowers that resisted realistic expression in carving and appear rather like cones. North and Cumming have attempted to portray the flowers as well as the cones, but only the latter are successful in carving. The stems emerge from Celtic ribbon-work.

Phyllocladus aspleniifolius celery-top pine is an endemic Tasmanian conifer that grows in wet forests and highland slopes. In place of needles, there are lobed cladodes, and instead of female cones, the tree produces fleshy flower-like fruiting bodies. As a result of these peculiarities, the conifer superficially resembles a flowering plant. Although less celebrated than the other endemic pines, it is undoubtedly the best suited to sculptural representation.

Blandfordia punicea Christmas bells is a lily endemic to high rainfall areas in Tasmania that in summer produces pendulous red flowers with yellow tips on stems up to a metre tall. The sculptured design is very true to the plant, although compacted for the purpose of composition. The ribbon-work on the shaft resolves into leaves that may be mistaken for a stem. This capital has suffered damage unsatisfactorily replaced by plain work, probably due to failure of adhesion of the render, suggesting that it may have been an early attempt at the work (plate 6).

Correa reflexa common correa has already been noted as one of the most strikingly successful designs. Its stems emerge from elaborate rectilinear knot-work that appears to combine Celtic and Oriental influences; unusually, it is continued up to the branches. The massing of the plant forms is sparser than in most of the other capitals, and the arrangement of the stems less naturalistic and more related to Art Nouveau stylisation. In design and execution, this is the masterpiece of both North and Cumming.

Eucalyptus amygdalina black peppermint, is an endemic tree growing throughout the drier parts of Tasmania. It produces timber formerly highly valued for its splitting qualities, used as shingles, weatherboards, palings and rails

for post-and-rail fences. The narrow almond-like leaves that led to its generic name are not usually as curved as they appear in the carving.

Anopterus glandulosus appears twice in the series, and the photograph of Cumming at work was taken when what is probably the earlier of the two was being made. The foliage is particularly dense, and the stems emerge from knotwork of clearly Celtic inspiration.

Eucalyptus globulus blue gum, is a tree that can grow to fifty metres in height and is highly valued for hardwood timber. Its locally-sourced timber is traded as Tasmanian Oak; its flowers are the floral emblem of Tasmania, but the rough-surfaced gumnuts are more suitable to the carved design, which is a particularly 'Art Nouveau' representation of the species. The stems emerge from knot-work that has foliations in a Mediæval manner. Most of the furniture in St John's is made of wood from this, or closely related eucalypt species (plate 7).

Alexander North's botanical sympathies were clearly with southeastern Australia and not solely with Tasmania, as his masterpiece is the chapel of Trinity College in the University of Melbourne in Victoria, begun in 1914 and completed in 1917 with his Hobart-born junior partner, Louis Williams (1890–1980). There, the decoration includes plant forms, and the ends of choir stalls are decorated with carvings of native animals, and some of these appear also in woodwork at St John's.

Of the plants chosen for the St John's capitals, six are Tasmanian endemics, and North may at the time have believed others to be so. His interest in timber trees is reflected in four of the choices, the two eucalypts, the blackwood and the celery-top pine. This last may have been chosen to represent its compatriot endemic conifers, the King William pine (King Billy) *Arthrotaxis selaginoides,* the Huon pine *Lagarostrobos franklinii*, and the South Esk pine *Callitris oblonga* as these were not likely to be recognisable in sculptured representation. The Tasmanian blue gum *Eucalyptus globulus* grows also on Bass Strait islands and on Cape Otway and Wilson's Promontory in Victoria. The botanist, Thomas Burns, noticed that prominent specimens planted in Launceston flowered at the same time as those in Victoria, and not with most of their Tasmanian cousins, and speculated that the seedlings may have been brought across the Strait (Burns 1974).

The sculptured iconography of St John's Church is quite limited in content, and it is yet to be finished. Other than the botanical capitals, the only completed scheme is that of the six pendentives of the dome, roundels surrounded by clover or shamrock leaves, traditional symbols of the Trinity, but probably alluding to the Irish connections of the two longest serving rectors of the parish: the Reverend Dr Browne, the second, and Canon Brownrigg, the longest serving incumbent. Two of the roundels contain Greek crosses, the other four the traditional 'evangelical symbols'

Plate 7 – St John's capital featuring blue gum *Eucalyptus globulus.* (copyright All Saints Anglican Network)

representing the alleged writers of the four canonical Gospels: the man, lion, calf and eagle. The uncarved blocks of stone in the corners of the crossing were reportedly intended to carry the heraldic arms of the successive dioceses to which the parish had allegiance. Otherwise, the carvings are almost entirely of plant forms, the most elaborate of those finished being on the tympanum of the north door, oak branches that appear in constant motion as if lashed by a high wind. This is a Church of England, its architect an exiled Englishman. The foliage surrounds a mandorla containing an inconspicuous cross, a very 'Low Church' emblem: no crucifix, no enthroned Christ. The Evangelical tradition of the parish probably explains the absence of strongly symbolic motifs, and the vegetable representations, whether naturalistic or stylised in either a Mediæval or an Art Nouveau fashion, must be regarded as purely decorative, acceptable as part of the architecture or as representations of works of the Creator. In the nave, the capitals demonstrate the botanical naturalisation of the exiled Englishman.

For purposes of comparison, it is instructive to consider some much earlier examples of the use of plant motifs by Alexander North and Harold Masters. The spandrels of the arch over the main entrance to the Launceston Post Office are decorated with escutcheons emblazoned with the Union Flag, one with the lion badge of Tasmania superimposed, and entangled with plants emblematic of Britain and the Colony (plate 8). The Tasmanian side has the blue gum entangled with the English oak, the 'Home' side more variously vegetated, probably in recognition of the other parts of the United Kingdom. All are arranged to occupy the space, but otherwise represented naturalistically, and carved in sandstone, probably by Sylvanus Wilmot (plate 8). Other spandrels on the same building have birds perched on the vegetation. Over a quarter of a century later, North's partner and collaborator, Harold Masters, decorated the *Launceston Examiner* office with stylised Art Nouveau rose bushes, applied to an Edwardian Free Style building of brick and concrete. The plants are wholly stylised in a fashion most often displayed on fireplace tiles and wallpapers of the preceding decades; a British commercial domestication of a Continental style suspected of being *decadent.* Naturalistic architectural decoration and Art Nouveau did not long survive the First World War, but they remained in the eclectic mind of Alexander North and issued in the anachronistic capitals he designed for St John's.

Belated for their style, unusual for their subject, uncommon in their material, remarkable in their accomplishment, a feature of a building that is no beauty, but has its beauties, and is unique in all the world, the botanical capitals of St John's are in my opinion a hidden treasure of national importance.

Plate 8 – Spandrel over the entrance archway of the Launceston Post Office, designed by Alexander North in 1885, and probably carved by Sylvanus Wilmot, combines English oak with Tasmanian blue gum. (Author's photograph 2020)

ACKNOWLEDGEMENTS

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(accepted 5 September 2024)

A COMPENDIUM OF THE EFFECTS OF LIMING MATERIALS ON CROP, PASTURE AND SOIL CHARACTERISTICS IN TASMANIA, AUSTRALIA, FROM 1940 TO 2020

by Barry A Rowe

(with four figures, three tables and four plates)

Rowe, BA (2024). A compendium of the effects of liming materials on crop, pasture and soil characteristics in Tasmania, Australia, from 1940 to 2020. *Papers and Proceedings of the Royal Society of Tasmania* 158: 25-38. ISSN: 0080-4703. Tasmanian Institute of Agriculture, University of Tasmania, Box 3523, Burnie, Tasmania 7320, Australia. Email: barry.rowe@utas.edu.au

Crushed agricultural limestone and dolomite are used primarily to increase soil pH (pH_w) with its consequent effects on plant nutrient availability and successful introduction of *Rhizobium* spp. to ensure effective nodulation and nitrogen fixation by pasture and crop legumes. They have also been shown to correct calcium deficiency and, in the case of dolomite, magnesium deficiency as well. Positive effects of liming recorded in Tasmania include increasing phosphorus availability, correcting molybdenum deficiency, ameliorating toxicities of manganese and aluminium, reducing crop cadmium concentrations in root crops, reducing phosphorus leaching, improving soil structure and negating soil acidification processes. Negative effects of liming that have been reported include inducing boron deficiency and encouraging plant disease. Options for future research are canvassed.

Key Words: calcium, magnesium, pH, nodulation, nitrogen fixation, phosphorus, molybdenum, manganese, aluminium, cadmium, boron, deficiency, toxicity, plant disease.

INTRODUCTION

Ground limestone and dolomite have been widely used in Tasmanian agriculture to neutralise natural acidity of acid soils as well as the acidifying effects of nitrogen fertilisers and atmospheric sulphur from marine and industrial sources. Burnt limestone products have been mixed with superphosphate to neutralise acidity of superphosphate as well as in mixtures with copper and sulphur to produce fungicides (Rowe 2023).

Annual production of agricultural liming materials in Tasmania increased from four kilotonnes (kt) in 1940 to 207 kt in 2001 before declining to an average of 145 kt between 2006 and 2020. Sources of various liming materials, their cost, transport, quality control and current usage have been reviewed (Rowe 2023). Soil types are as described in the original papers. Their acidity and distribution in Tasmania are as described (Nicolls & Dimmock 1965, Rowe 2023) and their putative attribution to the soil orders of the Australian Soil Classification Scheme (Isbell 2002) are shown in brackets (Cotching *et al.* 2009, Rowe 2023). This paper should be read in conjunction with its companion paper (Rowe 2023).

Prior to 1970, research concentrated primarily on the immediate effects of liming at rates up to 2.5 t/ha on growth of pasture legumes and annual vegetable and fodder crops. There are no reported investigations of liming effects on soil pH_w apart from establishing target pH_w values to ensure plant establishment and growth.

Around the mid-1970s, problems associated with soil acidification were becoming recognised around Australia mainly due to occurrences of manganese and aluminium toxicity. The latter was of particular concern where acidification occurred deeper in soil profiles (Bromfield *et al.* 1983) where it was difficult to remedy. Nutrient deficiencies and toxicities that are corrected or induced by liming are often identified by visual symptoms on plant leaves or fruit (Wallace 1943, Millikan 1953, 1958, Wallace 1961, Grundon *et al.* 1997) and/or plant nutrient levels in leaves (Smith & Loneragan 1997) or soils (Peverill *et al.* 2001). These diagnoses are often confirmed by measuring plant responses to liming materials in glasshouse pots or field plots.

Direct effects of liming to correct calcium and magnesium deficiencies in Tasmania are reported. Furthermore, benefits and/or disadvantages of liming on yield and/or quality of pastures and crops are recorded. Underlying mechanisms associated with responses to increasing soil pH_w are reported where they were identified. Effects of liming on changes in soil profile pH_w were investigated primarily on Krasnozems (Ferrosols) in northern Tasmania.

This paper documents the many roles that liming materials play in Tasmanian agriculture. However, the review is also relevant to comparable soils in Gippsland and western Victoria in cool temperate Australia (Paton & Hosking 1970) as well as similar soils nationally and internationally.

Application rates of limestone/dolomite

Application rates of limestone/dolomite rarely exceeded 2.5 t/ha when applied to cultivated seedbeds prior to establishing pasture (McCutcheon 1989), forage crops (Lamp 1966), and vegetable or field crops. However, in some cases lower rates are drilled with the seed. Similarly, rates in excess of 2.5 t/ha were rarely applied to established pastures (Paton 1960). Despite relatively slow dissolution rates of some particles in commercial limestone/dolomite products (Stackhouse 1985,

Rowe 2023) responses to liming were invariably recorded within the first growing season (≤ 6 months).

By the mid-1970s, effects of agricultural limestone at rates in excess of 2.5 t/ha were being investigated, with rates up to 15 t/ha being evaluated on pasture (Rowe 1982, Rowe & Johnson 1988), 20 t/ha on a sequence of annual crops (sugar beet, poppies and onions) (Anon 1981, Temple-Smith 1982, Temple-Smith & Laughlin 1985a, 1985b), 40 t/ha on potatoes and carrots (Sparrow *et al.* 1993a, 1993b, Sparrow & Salardini 1997) and up to 100 t/ha in preparing soils to grow French truffles (Garvey & Cooper 2004).

Calcium and magnesium deficiencies

Limestone and dolomite are sources of calcium and, in the case of dolomite, magnesium as well. Calcium and magnesium deficiency were widespread on yellow podzolic soils (Kurosols) in orcharding areas in southern Tasmania prior to the mid-1960s. However, only calcium deficiency has been reported to occur in pastures and field and vegetable crops.

Calcium deficiency

Symptoms of 'bitter pit' in apple fruit, which are attributed to calcium deficiency, have occurred in all orcharding areas of Tasmania but particularly in the Huon Valley. The cause of 'bitter pit' was investigated (Martin *et al.* 1960, Martin *et al.* 1962) and symptoms were dramatically reduced under field conditions by applications of 5–6 calcium sprays (e.g., calcium chloride or calcium nitrate at 5–8 g/l) applied from the calyx stage (Matthews & Wilson 1961, Raphael & Richards 1962). 'Bitter pit' occurred primarily in dry seasons in unirrigated orchards even where limestone had been applied in an attempt to alleviate the problem.

Isolated cases of calcium deficiency have also been reported in peaches (Ward 1955). 'Withertop' or 'flaxwilt' in flax *Linum usitatissimum*, resulting from calcium deficiency, was recorded in 1949 in Tasmania (Sampson & Walker 1982). It is due to a temporary deficiency of calcium in flax plants induced by waterlogging of soils during the stage of rapid elongation (Millikan 1944). It is evidenced by a weakening and toppling of stems 75–100 mm from the tip of the plant causing stems to be much reduced in length. It can be avoided by heavy dressings of limestone (Millikan 1944, Wade 1949a).

Calcium deficiency in pasture and forage crop species has been reported on strongly acid coastal sandy heathland soils (Podosols) in far northwest Tasmania and on Flinders Island (Fricke 1965).

Magnesium deficiency

Reports of magnesium deficiency are even rarer than those of calcium deficiency. Magnesium deficiency symptoms were reported to occur in apples due to a physiological imbalance caused by excessive use of potassium fertilisers. This problem occurred on all soils and varieties in the Huon Valley in the late 1950s. The recommended remedy was to cease potassium applications, apply Epsom salts in 5–7 sprays from the calyx stage and to apply dolomite at 1.6 t/ha (Ward 1957, 1958).

Increased phosphorus availability due to liming

In early pot experiments, incorporation of a range of alkaline materials at rates equivalent to 2.5 t limestone/ha to the surface 12.5 mm of a lateritic podsol (Kurosol), known locally as Cressy clay loam, showed that pH_w of the surface 12.5 mm of soil needed to be raised to pH_w 7.0 for responses in both the presence and absence of applied superphosphate to be maximised. Responses were attributed to a decrease in anion exchange capacity as pH_w increased from 6.0 to 7.0 and a consequent increase in availability of phosphorus (Stephens *et al.* 1942). Subsequent research showed that at least part of the yield response of white clover due to liming on this soil resulted from the release of molybdenum as pH_w increased to a pH_w of 7.0. However, a small part of the response was still attributable to the release of phosphorus (Stephens & Oertel 1943).

Associated increases in pH_w were confined to the surface 12.5 mm of the pots indicating that whatever mechanism produced the response, it was active within this shallow layer. Subsequent research using lime and other plant nutrients applied to the surface of soil and pasture did nothing to suggest that responses were other than those associated with surface effects, at least until the 1980s when responses to heavy rates of limestone began to be reported.

About 40 years later, grain yield of nitrogen and phosphorus (50 kg P/ha) fertilised barley grown on a Krasnozem (Ferrosol)(pH_w 5.0) containing high levels (77 ppm) of bicarbonate extractable phosphorus (Colwell 1965) increased linearly by 100 kg/t of limestone applied. In the absence of applied phosphorus, limestone increased barley yield by 230 kg/t of limestone, whereas in the presence of phosphorus, the increase averaged only 100 kg/t of limestone applied. This indicates that at least part of the effect of liming is to release phosphorus (Russell 1986).

Molybdenum deficiency and the role of agricultural liming materials

Pasture legumes

Recognition that molybdenum is required in trace amounts for plant growth and nitrogen fixation (Arnon & Stout 1939) was followed in 1942 by a report of molybdenum deficiency on a South Australian ironstone soil (Anderson 1942).

Subsequently, responses to molybdenum were recorded in clovers grown in pots on an ironstone soil from near Cressy in northern Tasmania (Stephens & Oertel 1943). This soil is a lateritic podzolic soil (Kurosol) known locally as Cressy Shaley clay loam. Subsequently, Fricke (Fricke 1943, 1944, 1945a, 1945b) showed that molybdenum deficiency in pasture legumes was widespread in the Northern Midlands, northeastern and northwestern districts of Tasmania. Since then pasture (clover) responses to molybdenum were obtained in most developed areas of the state (Paton 1956a).

Later it was shown that, where responses to dressings of limestone (2.5 t/ha) were recorded on well-established clover pastures, equivalent responses were obtained with molybdenum. It was concluded that the main effect of lime on many Tasmanian soils is to increase availability of molybdenum to pasture legumes (Paton 1960). The current recommended rate of molybdenum application to legume pastures is 60 g Mo/ha, applied no more frequently than once every five years (TempleSmith & Munday 1976).

Crops legumes

Similarly to pasture legumes, molybdenum was shown to improve nitrogen fixation and growth in green peas (Wade 1952) and blue and grey peas (Tilt & Taylor 1954).

Brassica crops

It has been shown that 'whiptail' in cauliflowers, as evidenced by the reduced size, puckering, distortion of leaf blades and irregular leaf margins when grown on some acid soils, can be corrected by liming. However, 'whiptail' can be corrected by molybdenum applied mixed with superphosphate (Wade 1949a, 1949b).

Role of liming in nodulation and nitrogen fixation

Pasture legumes

A strain of *Rhizobium trifolii* was selected in 1953 from nitrogen fixing nodules growing on roots of subterranean clover (*Trifolium subterraneum* cv. Mt Barker) growing in a Podosol on the property, 'West Thorpe', on the Waterhouse Estate about 20 km east of Bridport in northeast Tasmania (Morling pers. com.). Prior to this time, available commercial strains for subterranean clover were largely ineffective. Subsequently, this strain was shown to produce effective nodules on the roots of both white clover *Trifolium repens* and subterranean clover *Trifolium subterraneum* that resulted in spectacular increases in clover growth (Paton 1957). It was subsequently designated as strain TA1.

Effective nodulation and efficient nitrogen fixation of pasture legumes using TA1 depends on introduction and survival of effective rhizobia near the germinating seed and correction of nutrient deficiencies. Successful introduction of inoculum into the soil involves both inoculum survival on the seed prior to and during sowing and then its survival in the seedbed. It usually involves adhering rhizobia in a peat inoculum to the seed using an adhesive such as Gum Arabic or Cellofas A and then applying a coating of powdered limestone, dolomite or Plastaid® (Walker 1969a, 1978, Rowe & Johnson 1985, 1990) to the surface to improve survival of rhizobia on the seed surface until sowing. The physical and chemical properties of Plastaid® are described (Rowe 2023). These coatings also protect rhizobia from acidity of fertiliser when seed and fertiliser are mixed together before sowing. Other strategies to ensure inoculum survival during sowing include sowing the seed and fertiliser from separate seed boxes or sowing with limestone alone, with basic superphosphate (50:50 limestone-superphosphate mix) or with reverted superphosphate (15:85 burnt lime-superphosphate mix) (Paton 1957, 1960).

Survival of Rhizobia in soil is dependent on soil pH_w in contact with the germinated seed. Research, predominantly on wet heathland (Podosols), swamp soils (Organosols), and Krasnozems (Ferrosols) has shown that successful nodulation and nitrogen fixation can be assured if ground limestone/dolomite is applied at rates and by methods that vary according to soil type and seedbed acidity measured in a 1:5 soil: water mixture (pH_w) or in a 1:5 soil: 0.01 M $CaCl_2$ mixture (pH_{Ca}) for virgin or newly developed soils as shown in Table 1 (McCutcheon 1989).

Target pH_w were higher on Krasnosems for each recommended rate of limestone/dolomite application rate probably because of their higher buffering capacity. On Krasnozems (Ferrosols), 2.5 t/ha was recommended to be applied and worked into the soil surface prior to sowing when pH_w was <5.2, whereas limestone drilled with seed at 250–375 kg/ha was recommended when pH_w of Krasnozems (Ferrosols) was 5.2–5.5. In contrast, on other acid soils 2.5 t/ha was recommended to be applied and worked into the soil surface prior to sowing when pHw was <4.8, whereas limestone drilled with seed at rates of 250–375 kg/ha was recommended when pHw was 4.8–5.2.

Apart from liming, the full potential of the nitrogen fixation process is dependent on correction of widespread deficiencies of phosphorus (Paton 1956a, Paton & Hosking 1970), potassium (Paton 1956b) and molybdenum (Paton 1956a), whereas copper and zinc deficiencies have limited nitrogen fixation on wet heathland/swamp soils (Podosols and Organosols) on Flinders Island, King Island and in northern Tasmania (Paton & Hosking 1970). Sulphur deficiency rarely occurs except on Podosols in north-east Tasmania (Martinick 1974) where annual contributions of sulphur from fertilisers (e.g. superphosphate) and sulphur in rainfall from maritime (Martinick 1974, Blair *et al.* 1997) and industrial sources (Martinick 1974) were insufficient to prevent sulphur deficiency. Consequently, sulphur supplementation using sulphur fortified superphosphate containing an extra 280 kg of elemental sulphur per tonne

TABLE 1 — Target pH_w measured in 1:5 soil-water or pH_{Ca} measured in 1:5 soil to 0.01 M calcium chloride suspensions to guide application rates of agricultural limestone to ensure satisfactory nodulation and nitrogen fixation of white (*Trifolium repens)* and subterranean clover (*Trifolium subterraneum*) (McCutcheon 1989).

Rate (kg/ha) of limestone/ dolomite to be applied	Krasnozems (Ferrosols) pH_w	Other soils pH_w	Virgin soils pH_{Ca}
Nil	> 5.5	> 5.2	> 4.3
250–375 Drilled with seeds	5.2–5.5	4.8–5.2	3.9–4.3
2,500 Broadcast on soil surface	< 5.2	< 4.8	< 3.9

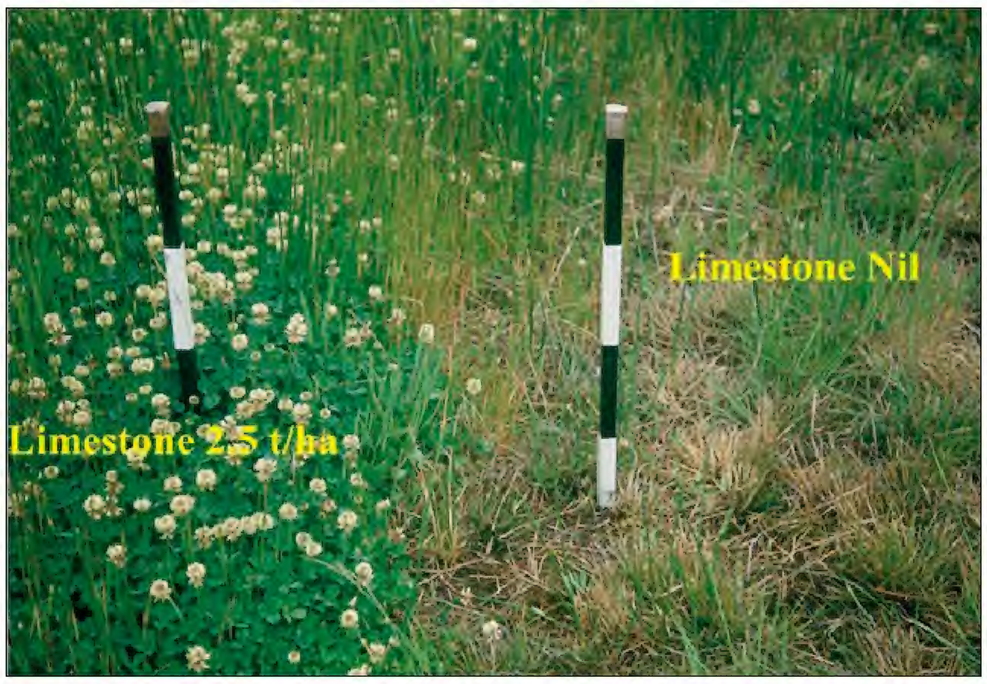

PLATE 1 — The effect of agricultural limestone broadcast at 2.5 t/ha on the surface of a Podosol (pH_w = 4.2) and worked into the surface on the establishment and growth of white clover *Trifolium repens* shown on the left of the photo compared to that on unlimed soil.

of superphosphate was warranted (Fricke 1969). Iron pyrites, as a slow-release sulphur source, was shown to be an effective sulphur source for these soils (Banath 1969) but was not used commercially.

Other pasture and crop legumes

The same principles and practices used for clovers have been applied to ensure satisfactory nodulation and nitrogen fixation in other pasture and crop legumes. Specific strains of rhizobia required to produce effective nodules on different legumes species (McCutcheon 1989) include: Rhizobia Group (RG) A is used on *Medicago* spp. including lucerne; RG – B is used on white, red, strawberry and shaftal clovers; RG – C is used on rose, cupped and crimson clovers and all subterranean clovers; RG – D is used on lotus major and birdsfoot trefoil; RG – E is used on peas, vetches, tares and faba beans; RG – F is used on beans including French, Navy and climbing beans; RG – B is used on lupins and serradella.

TABLE 2 — Target soil pH_w values for effective establishment of Lucerne (*Medicago sativa*) and a range of vegetable crops based on glasshouse and field experiments together with local observation.

Crop	Depth (mm)	Krasnozems (Ferrosols)	Reference
Lucerne		6.0	Kjar 1967
		6.0–7.0	Halpern 1966
		≤ 5.7	Anon 1982
Carrots		5.7–6.5	Walker & Walker 1970
Green beans		5.7–7.0	Walker 1969b
Onions	0–300	6.5–7.0	Walker & Cox 1970
Peas		6.0	Allen & Frappell 1961
Poppies		≥5.5	Allen & Frappell 1970

Target soil pH_w for satisfactory growth of pasture legumes and other crops

Liming and the associated increase in soil pH_w increased the establishment of pasture legumes (table 1) and yields of vegetable crops, including potatoes, and forages in Tasmania (table 2). Target soil pH_w levels to guide application rates of limestone to soils growing different species have been developed from observation of visual symptoms of toxicities, field and glasshouse experiments and experience of farmers and their advisors (table 2).

Liming and the alleviation of manganese toxicity

Manganese toxicity has been recorded in forage and vegetable brassica crops grown on Krasnozems (Ferrosols) in northern Tasmania (Wade 1961, Lamp 1966). These include chou-moellier ≅ marrow stemmed kale *Brassica oleracea* and rape *Brassica napus* as well as cauliflower *Brassica oleracea*. A similar condition in the related crops: cabbage *Brassica oleracea*, swede *Brassica napus* and fodder beet *Beta vulgaris* has been observed (Wade 1961, Lamp 1966).

On Krasnozems (Ferrosols), manganese toxicity was associated with sheet erosion that exposed subsoils that contain manganiferous concretions which release manganese at low pHw (Lamp 1965). Symptoms of manganese toxicity in chou-moellier begin to appear when leaf manganese concentrations in leaf lamina reach 900–1,000 ppm DM and become severe at 2,500 ppm, with values of 4,200–5,000 ppm recorded (Lamp 1965, Lamp 1966).

The correction of manganese toxicity and increased yield of marrow stemmed kale due to applying limestone at 2.5 t/ha was attributed to increased pH_w rather than an increase in calcium per se since calcium, supplied as gypsum at a rate equivalent to that in limestone at 2.5 t/ha, did not correct manganese toxicity or increase yield. Furthermore, where roots were split so that half the root system was grown in soil with a pHw of 4.6 and the other half in soil that had been limed to 5.8 then root growth was equivalent in both the soil of pH_w 4.6 and 5.8. Similarly, plants grown where a segment of the profile had been increased to 5.8 showed increased root growth (Lamp 1965). In circumstances where manganese toxicity is due to low pH_w (< 5.5) then 2.5 t/ha of ground agricultural limestone is recommended to correct the problem (Lamp 1966).

Tolerance of a range of crop and vegetable species, including some Tasmanian bred cultivars (see * in list below), to increasing levels (10 to 800 μM) of manganese in solution culture was investigated (Temple-Smith & Koen 1982). They found differences in tolerance to manganese can be largely attributed to differences in manganese concentration tolerated in the shoot prior to the appearance of toxicity symptoms and growth depressions. Shoot 'toxicity threshold values' (μg Mn/g DM) for various species are listed in order of increasing tolerance: *poppy was 150; Brussel sprouts 280; Proctor barley 290; *Shannon barley 340; lucerne 380; green bean 500; green pea 840; oats 1,880; sugar beet 5,980; and lupins 10,500.

Reduced phosphorus leaching due to liming

Pastures grown on an acid sandy soil (Podosol) on Flinders Island and identified as Nala Sand (Dimmock 1957) exhibited poor growth and symptoms of acute phosphorus deficiency in the absence of heavy lime applications, even when normal dressings of superphosphate were applied. The primary effects of these heavy rates of lime (up to 10 t/ha) were attributed to reduced phosphate leaching as illustrated by retention of 82% of radioactive phosphorus in the surface inch (25 mm) of limed soil compared to only 33% in unlimed soil: autoradiographs (plate 2) further highlight this effect (Paton & Loneragan 1960).

Effects of heavy rates of limestone on soil pH_w

Studies on pH_w changes in soil profiles have been incidental to effects of liming on pasture and crop yields, reduction of aluminium toxicity and cadmium uptake. These studies were primarily conducted on Krasnozems (Ferrosols). Only the targeted increase in soil pH_w to provide a suitable environment for growing French truffles extended these studies to soils other than Krasnozems (Ferrosols).

The effects of lime rates up to 15 t/ha (Rowe 1982, Rowe & Johnson 1988), 20 t/ha (Temple-Smith *et al.* 1983), 30 t/ha (Sparrow & Salardini 1997) on pH_w were measured to a depth of 300 mm. The effects of 50 and 100 t/ha were only measured to a depth of 200 mm (Garvey & Cooper 2004).

Surface application to permanent pasture on Krasnozems (Ferrosols)

Applications of limestone in six annual increments of 2.5 t/ha (total 15 t/ha) to the surface of pasture increased pH_w of the surface 75 mm of a Krasnozem (Ferrosols) by 0.1 pH_w units/t (fig. 1A) (Rowe 1982). Subsequent reaction of limestone with the soil and leaching of calcium down the profile is evidenced by the linear decline in the surface 75 mm by 0.09 pH_w units/year over the next eight years (fig. 1b) (Rowe & Johnson 1988). This linear decline is shown to be a segment of an exponential decline from 1975 to 1996 (figs 1B, 1C) (Rowe & Johnson unpublished).

The change in soil pHw (Δ pHw) with increasing soil profile depth on the unlimed and limed plots is shown for measurements recorded in 1976 (fig. 2A) and 1984 (fig. 2B). The increase in soil pHw due to liming (Δ pHw) is shown in figure 2C. The peak of the pHw increase moved from the surface in 1976 to a depth of 125 mm in 1984, a distance of 75 mm in eight years. Furthermore, significant pHw increases were recorded deeper in the profile at a depth of 225–300 mm (Rowe & Johnson 1988). Concurrently, liming significantly increased pHw-dependent cation exchange capacity (CEC) (Bradley *et al.* 1983) of the soil (cmol+/kg) (table 3) (Rowe unpublished).

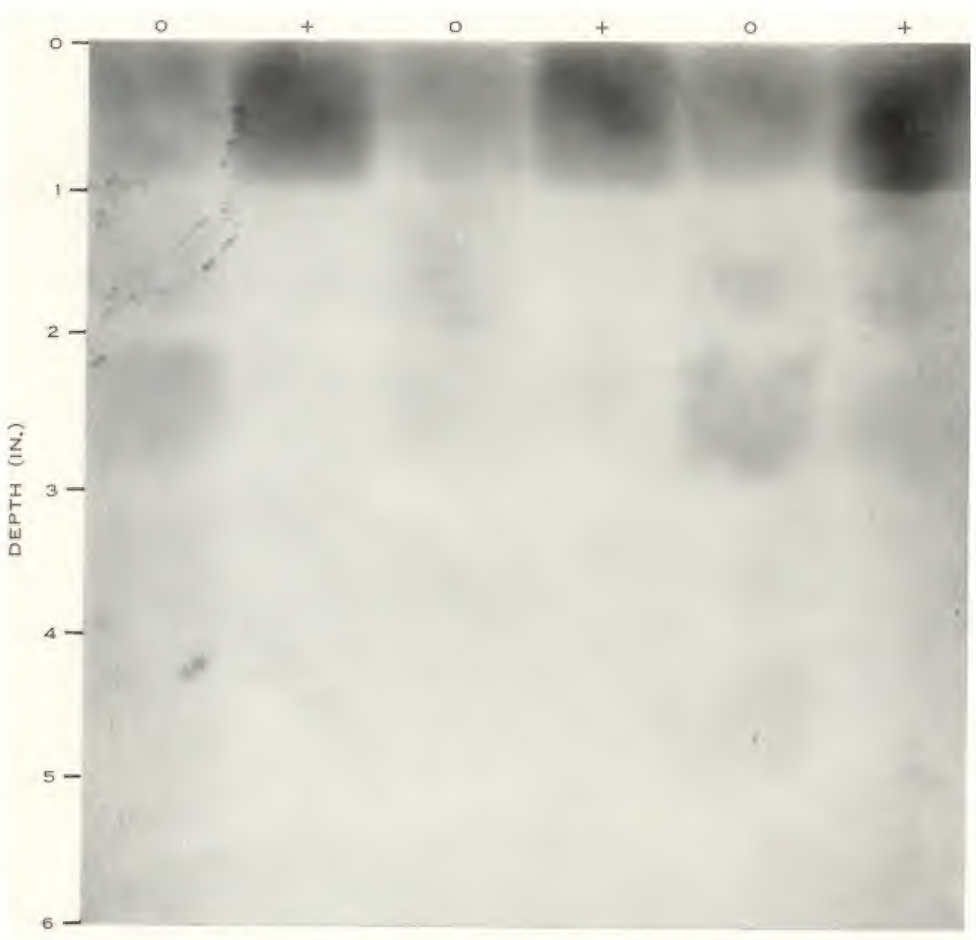

PLATE 2 — Agricultural limestone applied at 10 t/ha (+) reduced phosphorus leaching compared to no limestone (-) in a Podosol on Flinders Island (Paton & Loneragan 1960).

Effects on soil pH_w of surface application of limestone and subsequent mixing by cultivations on soil pH_w on Krasnozems (Ferrosols)

Effects of surface applications of limestone at rates of 0–20 t/ha to cultivated seedbeds on profile pH_w at two sites on Krasnozems (Ferrosols) following its incorporation using normal cultivation and sowing procedures used in establishing and harvesting a sugar beet crop (Anon 1981) and then sowing a poppy crop after harrowing and drilling inorganic fertiliser at depths up to 150 mm were measured 18 months after liming (Temple-Smith *et al.* 1983). PH_w of composite samples of 50 mm segments showed that pH_w declined from the surface 50 mm to the 50–100 mm segment with no detectable differences below 100 mm even when 20 t/ha of limestone had been applied (Temple-Smith *et al.* 1983).

However, sampling of individual segments showed that on unlimed plots pH_w had a range of 0.3–0.4 pH_w units with standard error (s.e.) of 0.08–0.14 in the three sampling depths at both sites indicating underlying micro variability of pH_w. Liming increased spatial variability as evidenced by both increased range from 0.6–2.2 pH_w units and s.e. from 0.19–0.68. This indicates that cultivations had not mixed limestone homogenously throughout the soil (Temple-Smith *et al.* 1983).

Surface application to cultivated seedbeds with major mixing cultivations

Effects of applying 30 t/ha of limestone on the soil profile pHw were measured to a depth of 300 mm two years after the limestone was broadcast to the surface (fig. 3A). Following application, the lime was mixed to a nominal depth of 150–200 mm using a rotary-hoe prior to further mixing during planting, ridging and lifting a potato crop, then followed by normal cultivations associated with sowing a poppy crop. Surface pHw were at a maximum of 7.1 in the surface 0–100 mm before gradually declining to 5.7 in the 250–300 segment. The largest pHw increases of 1.0–1.25 units were recorded in the surface 0–150 mm segment and declined to 0.2 units in the 250–300 mm depth.

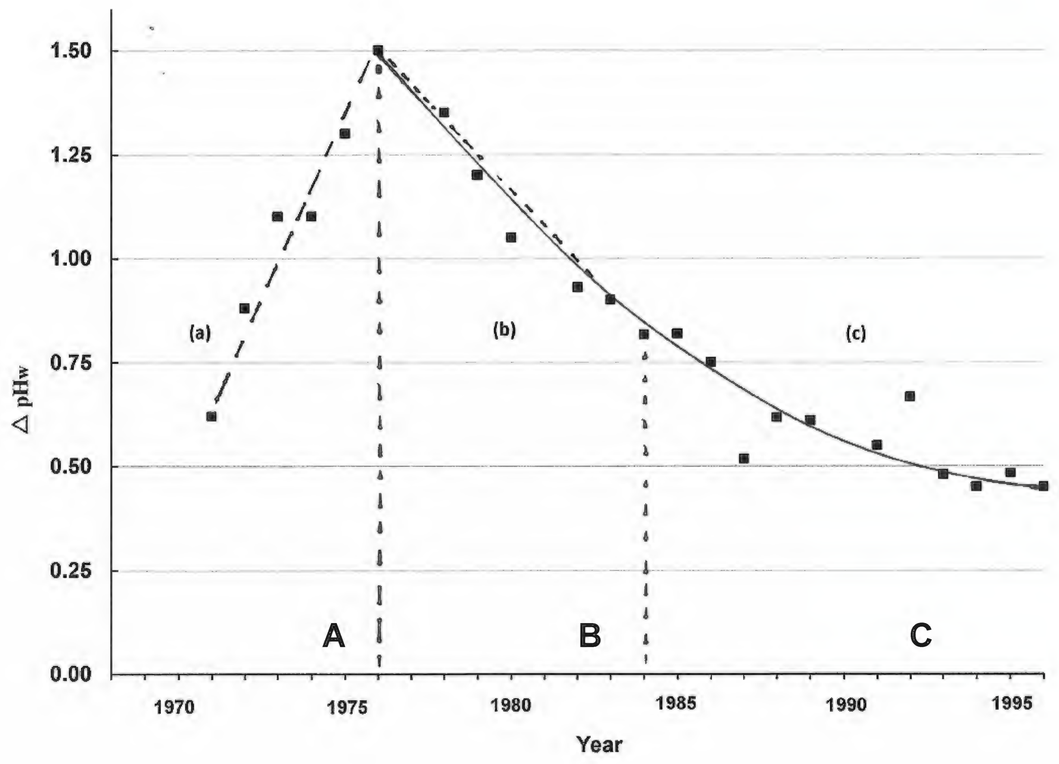

FIGURE 1 — Incremental changes (Δ pHw) in the surface 75 mm of a Krasnozem (Brown Ferrosol): (**A**) due to annual applications of limestone (L) at 2.5 t/ha between 1971 and 75 (Rowe 1982); (**B**) the subsequent decline in Δ pHw due to calcium leaching during the following eight years from 1976 to 1984 (Rowe & Johnson 1988); and (**C**) the decline in Δ pHw in the 12 years from 1984 to 1996. The curve describes the change in Δ pHw between 1975 and 1996 (Rowe & Johnson unpublished). ΔpHw = pHw of limed plots minus the pHw of the unlimed plots.

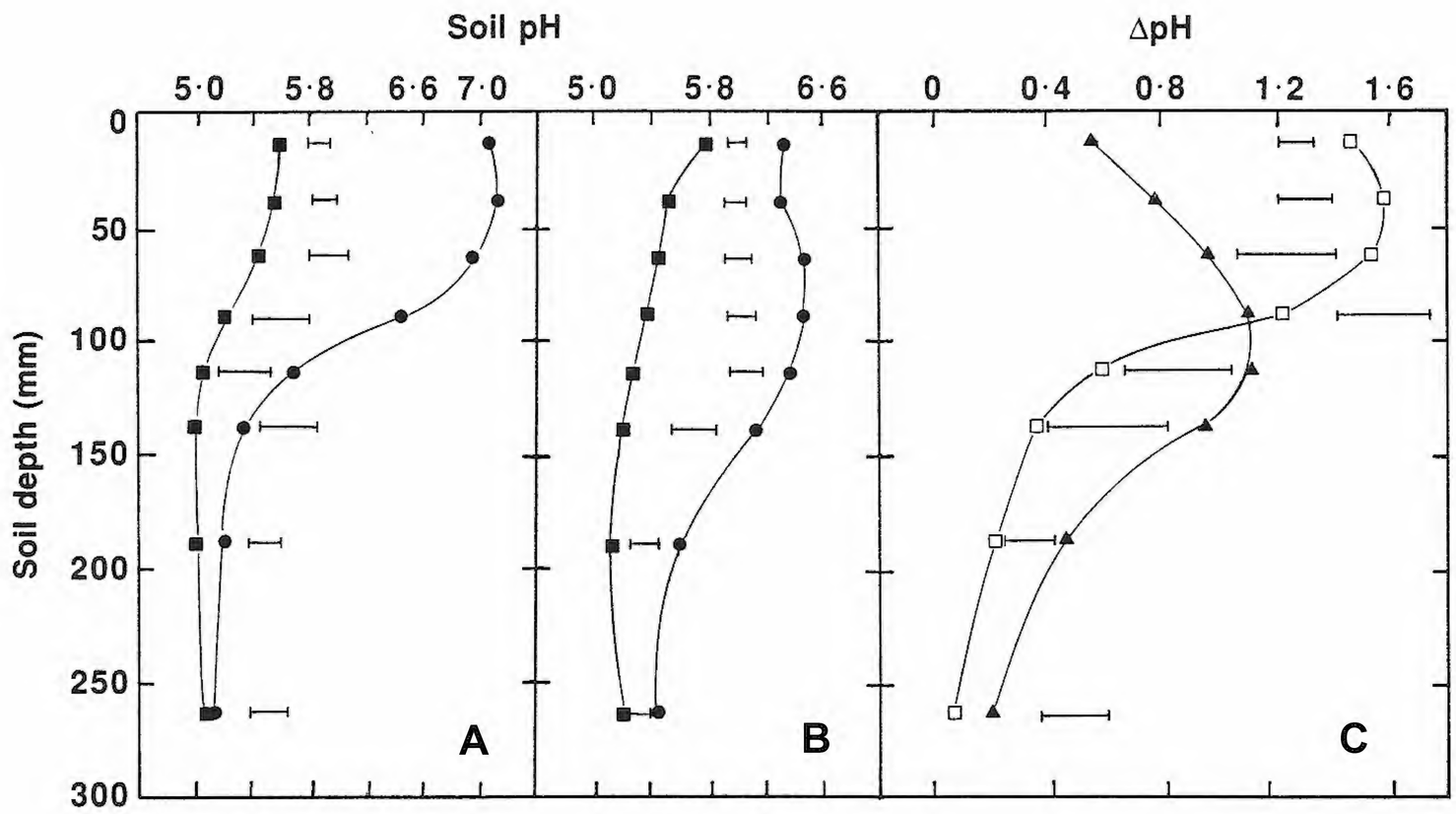

FIGURE 2 — The change in soil pHw with increasing depth of soil on limed (●) and unlimed (□) plots when measured in (**A**) 1976 and (**B**) 1984 (Rowe & Johnson 1988). (**C**) The increase in soil pH_w (ΔpH) due to the limestone applications throughout the soil profile in 1976 (□) and 1984 (▲) (1.5 and 9.3 years after the final application of limestone). The horizontal bars denote the l.s.d. (P=0.05).

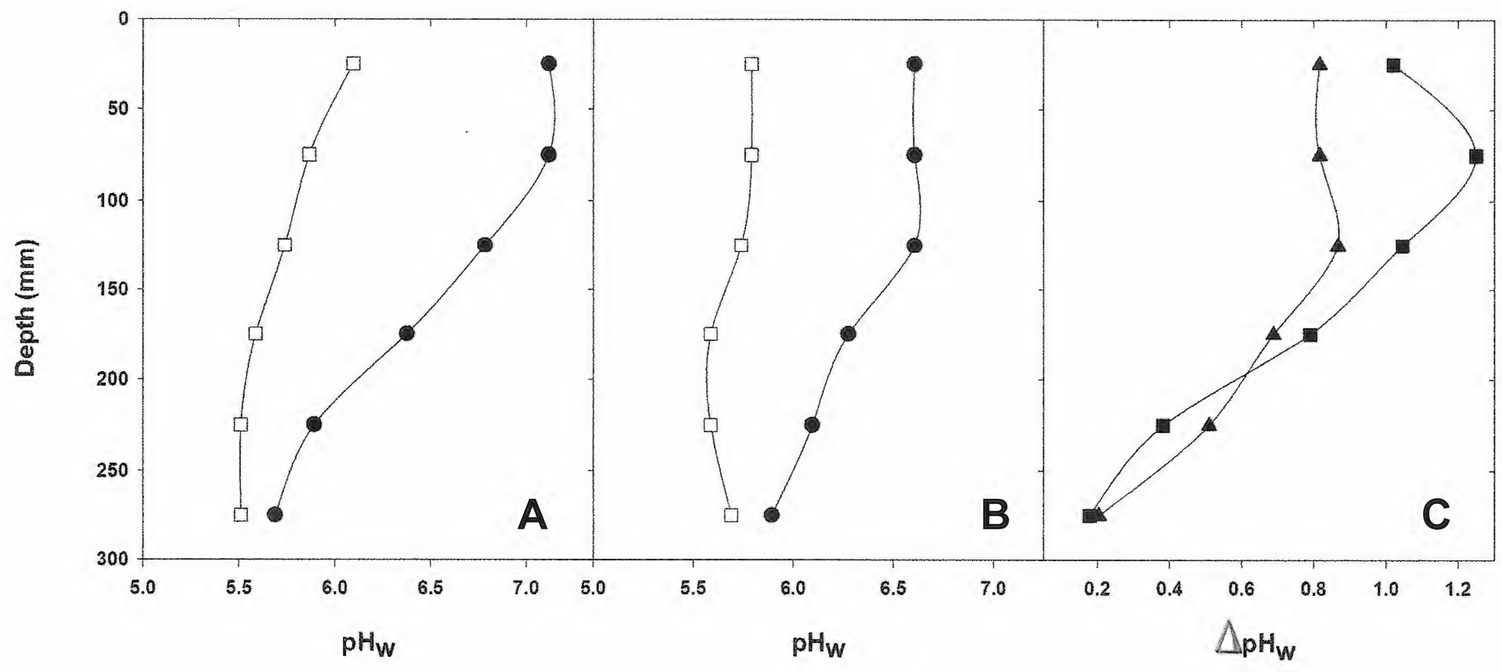

FIGURE 3 — The change in soil pHw with increasing depth of soil on limed (●) and unlimed (□) plots when measured in (**A**) 1992 and (**B**) 1995 (Sparrow & Salardini 1997). (**C**) The increase in soil pH_w (ΔpH) due to the limestone applications throughout the soil profile in 1992 (■) and 1995 (▲) (2 and 5 years after the application and incorporation of limestone).

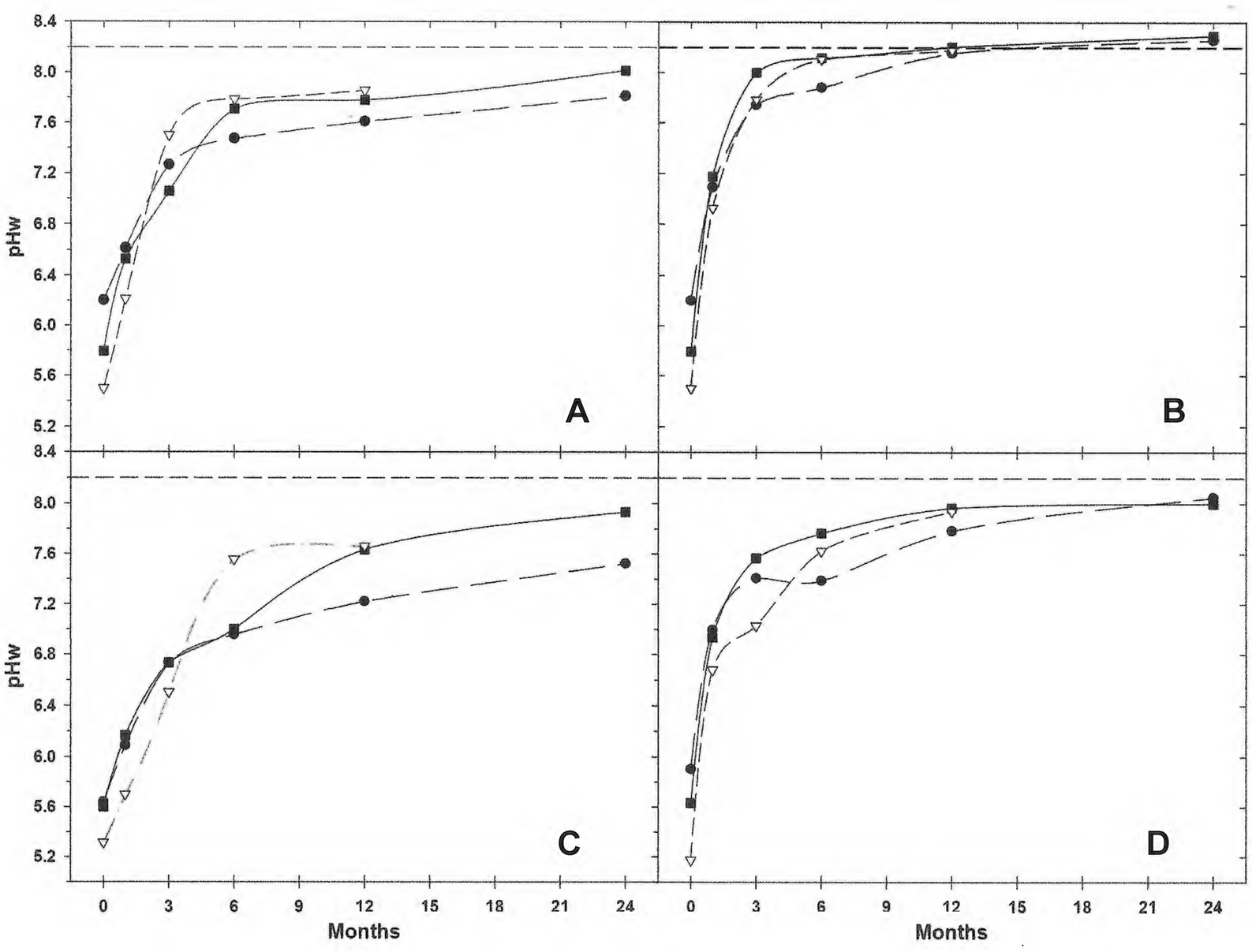

FIGURE 4 — Increases in soil pHw in a Krasnozem (Ferrosol) (●), a podzolic (▽) and an alluvial soil (■) when limestone was incorporated at 50 t/ha and measured in (**A**) the surface 50 mm and (**C**) at a depth of 100 – 200 mm. The increases in soil pH_w due to incorporating limestone at 100 t/ha in (**B**) the surface 50 mm and (**D**) at a depth of 100 to 200 mm. The horizontal dashed line represents the upper level of pH_w (8.2) in calcareous soils (Rengasamy 2022).

TABLE 3 — Increases in cation exchange capacity (cmol+/kg) (Bradley *et al*. 1983) with depth of soil profile due to liming.

Depth (mm)	Unlimed	Limed (15 t/ha)	Probability (P)
0–50	15.8	26.3	P <0.001
50–100	9.0	24.3	P <0.001
100–150	6.2	18.9	P <0.001
150–225	5.7	8.1	P < 0.01
225–300	5.3	6.6	P < 0.01

Soil profile pHw was measured again five years after the initial application of limestone following further mixing because of planting, ridging and lifting a second potato crop. At this time the surface 150 mm on limed plots had become less alkaline than when measured three years earlier (fig. 3B) with increases averaging 0.8 pH_w units in surface 150 mm (fig. 3C). Below this depth there had been very little change in Δ pH_w (fig. 3C) (Sparrow & Salardini 1997). This pattern of declining alkalinity at the surface and increasing alkalinity deeper in the profile with the passage of time is similar to that recorded in the soil profile (fig. 2) when limestone was applied to the surface of a permanent pasture (Rowe & Johnson 1988).

In the development of new trufferies, the objective is to raise pH_w above 7.5 and preferably to 7.9–8.1 to make the soils suitable to grow French truffles *Tuber melanosporum* (Garvey & Cooper 2004). Commercial limestone at rates of 50, 75 and 100 t/ha were incorporated with a disc-plough to a nominal depth of 200 mm followed by three passes of a tyned implement on a Krasnozem and an alluvial soil using limestone with a nominal particle size <2.00 mm and on a podzolic soil using limestone with a nominal particle size <1.00 mm. Increases in soil profile pH_w were measured at depths of 0–50 mm, 50–100 mm and 100–200 mm. Samples were collected prior to liming and 1, 3, 6, 12 and 24 months after liming. Replotting their data using a linear time scale revealed Mitscherlich type response curves describing increases in pHw versus sampling time for each soil and sampling depth.

Figure 4 presents a subset of this data to illustrate key features of the responses. In each instance pH_w increased rapidly from the starting pH_w to 90% or more of maximum during the first six months. Initial pH_w values ranged from 5.8–6.2 on the Krasnozem, 5.4–5.8 on the alluvium soil and 5.3–5.4 on the podzolic soil with lower pH_w values being recorded deeper in the profile. Maximum pH_w exceeded 8.0 at all depths 24 months after limestone was applied at 100 t/ha; maximum pH_w exceeded 7.8 at all other depths 24 months after limestone was applied at 75 t/ha. However, when 50 t/ha was applied, pH_w of the surface 0–50 mm exceeded 7.8, the 50–100 mm exceeded pH_w 7.6 and 100–200 mm exceeded pH_w 7.5 at 24 months after lime application. These maximum values are comparable to those recorded for calcareous soils in South Australia with a recorded range of 8.0–8.2 (Rengasamy 2022).

The conclusion from these studies is that reaction of limestone with the soil at the surface of a pasture and its movement down the profile is very slow and may well be reduced in soils where leaching of calcium ions is retarded by increases in the pH-dependent cation exchange capacity. Incorporation of limestone particles by rotary hoeing and normal cultivation methodologies primarily increases pHw of soil in the surface 100 mm, whereas deeper and more vigorous incorporation, as in growing two potato crops, did not substantially increase pH_w below 250 mm five years after application of limestone at 30 t/ha: the effects on pH_w remained primarily in the mixing zone.

Pasture yield increases due to heavy rates of limestone

Limestone applications totalling 7.5–15.0 t/ha significantly increased pasture dry matter yields from permanent, unirrigated ryegrass-white clover pasture (two sites) in more than half the harvests in summer, autumn and early spring, but not in late spring. These increases, which range from 200–1,200 kg/ha, occurred when feed supplies often restrict production from dairy herds grazing dryland pasture in north-western Tasmania. Significantly, these increases were not due to an increase in molybdenum availability associated with increases in soil pH_w (Rowe 1982).

At one of the above sites, it was shown that residual effects of having applied limestone at 15 t/ha increased annual dry matter production (DM) by 0.5–1.7 t DM/ha for at least nine years after the final application of limestone. The largest seasonal dry matter increases of 0.4–0.7 t DM/ha were recorded in autumn. It was calculated that costs of applying limestone at rates up to 15 t/ha at the then cost of $30/t would be repaid at an effective interest rate of 10% per annum within 12 years (Rowe & Johnson 1988).

Effects of limestone rates (0–10 t/ha) were investigated on established dairy pastures between 1992 and 1996, a period of three and a half years, on soils that included yellow podzolics in the Deloraine region, podzols, an acid peat and a silty clay loam in the Circular Head region around Smithton as well a site on a Krasnozem at Elliott (Freeman 1996):

(i) The three yellow podzolics (Kurosols) were very acid in the surface 75 mm (pH_w 4.7–4.9). However, the onset of significant yield increases, which occurred either 1.5, 2.5 or 3.5 years after treatments were applied, were related to the pHw in the 76–130 mm (pH_w 4.5–5.0) with the earlier response occurring where pHw was more acid deeper in the profile.

(ii) The three podzols (Podosols) had pH_w in the range 5.8–6.3 in the surface 75 mm but a bigger range in the 76–130 mm depth (pH_w 4.6–5.9). A marked increase in yield was only measured at one site which had pH_w of 5.8 in the surface 75 mm but a much lower pH_w of 4.6 in the 76–130 mm depth.

(iii) The acid peat had a pH_w of 5.5 in the surface 75 mm but no pH_w was recorded lower in the profile. An indication of a response to liming ($P < 0.10$) was recorded 3.5 years after lime treatments were applied.

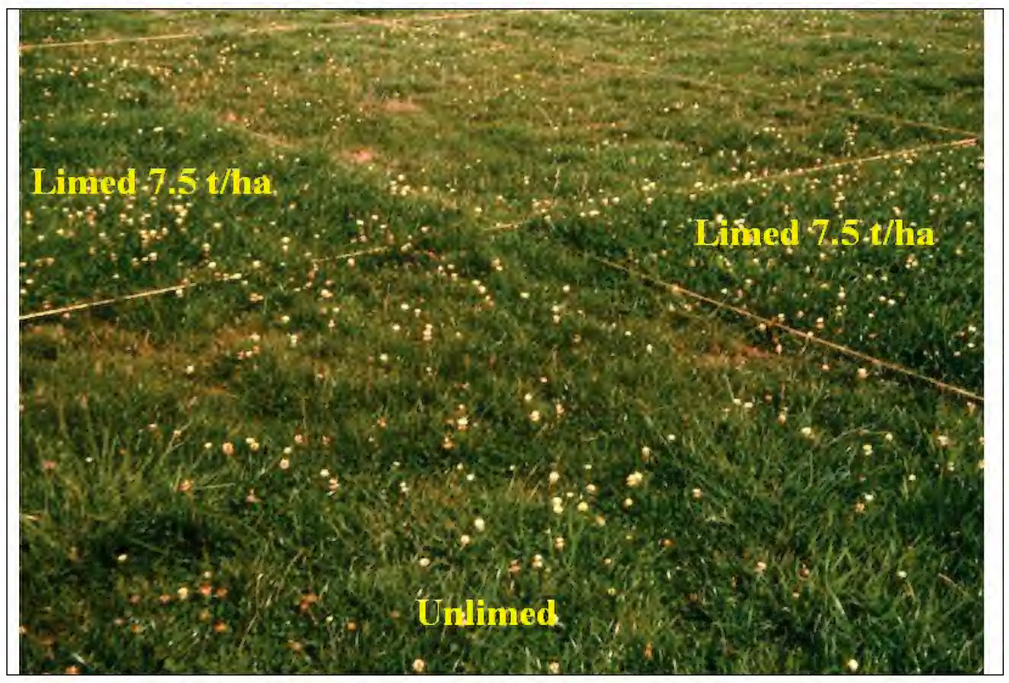

PLATE 3 — Effects of heavy rates of limestone (7.5 t/ha) on pasture grown on a Krasnozem (Ferrosol) with an initial pH_w of 5.5 when measured on 29 March 1973 at Central Castra (Rowe 1982).

(iv) The Krasnozem (Ferrosol) had an initial pH_w of 5.2 in the surface 0–75 mm and 5.0 in the 75–130 mm. Pasture yields increased linearly between limestone rates from 0.0–7.5 t/ha before decreasing at 10 t/ha when measured in the second and third autumns after application.

Aluminium toxicity

Field experiments using limestone to alleviate aluminium toxicity

Agricultural limestone was applied at rates between 0–20 t/ha on two Krasnozems (Ferrosols) with an initial pHw 5.1 and 5.4 following winter cultivation. Subsequently, its effects on spring-sown sugar beet (Anon 1981) and poppies (Temple-Smith *et al.* 1983) were measured at both sites in consecutive years. Its effects on onions (Temple-Smith & Laughlin 1985b) were measured at only one site (site with higher initial pH) in the third year:

(i) Sugar beet responded quite dramatically to increasing rates of limestone applied at rates of 0–20 t/ha on Krasnozems (Ferrosols) with pH_w 5.1 and 5.4 although satisfactory sugar yields from sugar beet (>10 t/ha) can be expected on soils with a pH_w of about 5.8. Increases in sugar yields were attributed to the correction of aluminium toxicity based on the high amount of misshapen roots and 'fanging' in plots where no limestone or low rates of limestone had been applied: these were associated with higher levels of extractable aluminium in the soil profile (Anon 1981). The effect cannot be attributed to manganese toxicity as sugar beet appears to be highly tolerant of manganese (Temple-Smith & Koen 1982).

(ii) Poppies were sown at the same two sites in the following spring. Responses to agricultural limestone applied in the previous year were measured (Temple-Smith *et al.* 1983). These experiments confirmed that poppies are extremely sensitive to soil acidity with effects being attributed primarily to the alleviation of aluminium toxicity. However, they noted that the relative effects of aluminium and calcium on yields could not be resolved

because the reductions in soluble aluminium and increases in calcium have been confounded by the application of lime. However, poor tap root development and abnormal lateral root growth is consistent with the stunted root growth of poppies when grown without lime or low rates of limestone. These effects were similar to growth of poppy roots when grown, even at relatively low concentrations of aluminium, in solution culture (Temple-Smith 1982).

(iii) Onion bulb yield (y) at dry maturity (t/ha) and soil pH_w of surface 0–100 mm increased linearly at each site in proportion to the rate of limestone (L) applied (y = 39.25 + 1.13 L; R^2 = 0.83; pHw =5.46 + 0.096 L; R^2 = 0.99) (Temple-Smith & Laughlin 1985a, 1985b). They found that 95% of the total root length was restricted to the surface 200 mm of soil where $pH_w \leq 5.0$ in the 200–300 mm segment. However, more than half of the root length was below a depth of 200 mm when pH_w in the 200–300 mm segment was 6.3. Highest yields were obtained when 40–60% of total root length was present at depths below 200 mm at the start of bulb formation.

A regression of the percent of total root length below 200 mm depth against soil pHw at a depth of 200–300 mm indicated that low subsoil pH_w was restricting rooting depth.

Aluminium solution culture experiment

A preliminary aluminium solution culture experiment was conducted to assess the relative sensitivity to aluminium toxicity and probable responsiveness to liming of ten crop and forage species used in Tasmania (Temple-Smith 1982). These included sugar beet and poppies that were used in the field experiments discussed above. However, onions were not included. This group of ten included some cultivars bred in Tasmania.

Shoot dry matter was a poor indicator of relative sensitivity of species to aluminium but root yields and root extension growth were both good indicators of aluminium toxicity. Sensitive species (barley, sugar beet, Brussels sprouts, poppy and lucerne) all produced the greatest root growth in solutions containing aluminium at 0 µM but in large-seeded legumes (lupin, green bean and green pea) low levels of aluminium (25–100 µM) stimulated root growth while higher concentrations depressed it.

Species were ranked in order from the least to most tolerant to aluminium based on root growth and the occurrence of aluminium toxicity symptoms on the roots: sugar beet, Brussel sprout, poppies and lucerne were less tolerant than the barley cultivars Proctor and Shannon. These were all less tolerant than oats, green bean and green pea which were all less tolerant than lupin.

Thickening and necrosis of primary (1°) and secondary (2°) apices were recorded at 25 µM aluminium for sugar beet, Brussels sprouts, poppies and lucerne. Thickening of 2° apices but without necrosis were recorded at 50 µM aluminium for both Proctor and Shannon barley. At 200 µM aluminium, green bean showed necrosis of 1° and 2° apices, green pea showed severe distortion and cracking of 1° and 2° roots while oats showed slight necrosis of 2° nodal apices. Lupins, on the other hand, showed thickening and necrosis of 1° and 2° apices at 400 µM aluminium.

PLATE 4 — The susceptibility of roots of Shannon Barley to increasing levels of solution aluminium from left to right: 0, 25, 50,100, 200 and 400 µM Aluminium (Temple-Smith 1982).

The report (Temple-Smith 1982) contains colour photos of roots of poppies, the barley cultivar Shannon, and lupin after two weeks of growth in a range of aluminium concentrations (0, 25, 50, 100, 200 and 400 µM Al). It also contains close-up views of aluminium toxicity on roots of poppy, sugar beet, Shannon barley, green peas and lupin.

Liming to reduce cadmium levels in potatoes and carrots

Until the early 1980s, the rock phosphates used to make phosphatic fertilisers contained relatively high levels of cadmium impurities. This, coupled with the intensive cropping history on Krasnozems (Ferrosols) and associated use of high rates of phosphate fertiliser has resulted in relatively high cadmium levels in the soil (Sparrow *et al.* 1992) with about 14% of Tasmanian soils producing potatoes exceeding the then Australian maximum permitted concentration of cadmium of 0.05 mg/kg fresh weight which equates to 0.25 mg/kg DM. Subsequently, this concentration was doubled to 0.1 mg/kg fresh weight (Sparrow pers. comm.).

Surface application of agricultural limestone to three different sites at rates of 0–30 or 0–40 t/ha did not reduce cadmium levels in potato tubers despite incorporation in the surface using a rotary hoe 4–12 weeks before planting. However, tuber cadmium levels increased as the amount of cadmium applied in phosphatic fertilisers increased (Sparrow *et al.* 1993a). Subsequently, residual effects of limestone applied (0–30 t/ha) on cadmium levels in potato tubers were measured at two of the above sites either two or three years later. This followed further mixing of limestone in the soil profile by potato harvesting machines and a further two or three years for limestone to react with soil. Tuber cadmium levels declined linearly in proportion to the rate of limestone applied by about 25% to values of about 0.1 mg/kg DM, equivalent to 40% of the permissible level.

Five years after limestone was applied at one of the above sites and following further mixing with a potato harvester,

carrots were sown and cadmium content of the roots was measured. Again, cadmium content declined linearly with the rate of limestone, by about 50%, to 0.06 mg/kg DM which is equivalent to 24% of the permissible level (Sparrow & Salardini 1997).

Liming improves structure and hydraulic conductivity of a Krasnozem (Ferrosol)

A softer soil surface that was subject to more summer cracking was observed after limestone was applied at 15 t/ha to the surface of an established pasture grown on a Krasnozem (Brown Ferrosol). Furthermore, liming decreased penetration resistance and increased hydraulic conductivity. These structural improvements were associated with increased dry aggregate size, a small increase in wet aggregate stability, higher exchangeable calcium levels, and increased plant growth, but a 9% decrease in total soil organic carbon in the surface 50 mm. Decreases in soil penetration resistance due to liming increased the likelihood of pugging from livestock but may improve the ease of tillage (Kirkham 2003, Kirkham *et al.* 2007).

Available water

Despite liming (15 t/ha) altering soil structure (Kirkham *et al.* 2007) it did not increase available soil water capacity of the soil under an unirrigated barley crop as measured by the difference between the moisture held at field capacity and wilting point. However, the rate of water extraction from higher yielding limed plots was greater than that from un-limed plots (Rowe & Johnson 1995).

In events when rainfall is sufficient to satisfy the soil water deficit on limed plots then the deficit on unlimed plots would be exceeded, and lost to deep drainage. In such an instance, limed plots would have a net gain in available water available for evapotranspiration during the growing season and, consequentially, potential for more growth.

Artemisia

Agronomic practices required to grow the medicinal crop, *Artemisia annua* L. to produce antimalarial constituents, artemisinin and artemisinic acid, were investigated to assess the potential of this crop to be grown in Tasmania. Plants grew to a height of up to 2.5 m at maturity (Laughlin *et al.* 2002) with antimalarial constituents concentrated in leaves and flowers (Laughlin 1995).

Fine-ground limestone applied at 10 t/ha to a Krasnozem (red ferrosol) increased soil pH_w from 5.0 to 5.5 and leaf dry matter yield of a Yugoslavian cultivar from 1.0 to 6.5 t/ha and a Chinese cultivar from 4.5 to 8.0 t/ha without affecting concentrations of either artemisinin or artemisinic acid in the leaves (Laughlin 1993). Subsequently, a pot experiment was conducted in a greenhouse using the same soil and strains of *A. annua* as above. Fine-ground calcium hydroxide was applied to the surface at rates equivalent to 0, 1.0, 2.5, 5.0, 10.0, 20.0 and 40.0 t/ha. The lime was then uniformly mixed through the soil to produce mean soil pH_w values of 5.0, 5.2, 5.3, 5.4, 6.0, 7.4 and 8.2. *A. annua* L. achieved maximum yield of both dry matter and antimalarial constituents at pH_w from 5.5–6.0 although some varieties have a wider tolerance of pH_w up to 8.0 (Laughlin 1993).

Liming to ameliorate plant disease

'Clubroot' or 'finger and toe' disease *(Plasmodiophora brassicae)* of cabbages, cauliflowers, broccoli and Brussels sprouts occurs throughout Tasmania. Heavy dressings of lime (5–10 t/ha) are often required on soils subject to this disease to ameliorate this problem (Wade 1949a, 1949b).

Negative effects of liming

Potato common scab *Streptomyces scabies*

Tasmanian potatoes are grown predominantly on Krasnozems (Ferrosols) where the incidence and severity of potato common scab has rapidly increased when cv. Russet Burbank became the primary processing cultivar in the state (Wilson 1996). The incidence of potato common scab has been shown to be negligible on Krasnozems (Ferrosols) with a $pH_w < 5.2$ but above this pH_w no effect was detected (Lacey & Wilson 2001).

Notwithstanding early reports that liming increased potato yields (Wilson 1949), perception amongst many potato growers is that liming increases common scab in potatoes and this remains a barrier to lime use in crop rotations in Tasmania. This is despite scab-free potatoes being grown on Krasnozems (Ferrosols) that have been limed to pH_w 6.0–6.5 and the occurrence of severe outbreaks occur at pH_w <5.5 (Sparrow & Salardini 1997). However, the occurrence of potato common scab at one site was exacerbated by limestone applied at rates up to 30 t/ha. In fact, levels of potato common scab made potatoes unsuitable for processing where rates of limestone at 20 and 30 t/ha had been applied (Sparrow & Salardini 1997). However, in this instance, this was the third potato crop in five years and potato common scab inoculum may have been substantial. It should be noted that potato processing companies require at least five years between successive commercial crops and the use of clean seed to minimise scab events.

Liming-induced boron deficiency

Boron deficiency has been recorded in pasture legumes on very acid heathland soils on the west coast of Tasmania following heavy liming (Paton & Hosking 1970). Expansion of the area of land sown to poppies in the 1990s coupled with competition for cropping land from vegetable crops necessitated a move from growing poppies on Krasnozems (Ferrosols) to lighter alluvial soils. This was associated with the occurrence of boron deficiency particularly under dry conditions (Laughlin *et al.* 1998). This problem was exacerbated by liming (Laughlin 1980).

Minor uses of lime in Tasmanian agriculture

(i) Powdered limestone, dolomite and cement together with lime-sulphur have all been used to encourage suberisation on cut potato sets, thereby protecting seed potatoes from fungal and bacterial infections while in storage prior to planting (Chapman 1977).

(ii) Lime-sulphur and Bordeaux mixture: Limil® is reacted with copper sulphate to produce Bordeaux mixture and with sulphur to produce lime-sulphur. The reaction products of each have been used as fungicides (Wade 1949a).

(iii) Introduction of earthworms *Aporrectodea caliginous* and *A. longa* into pasture soils devoid of earthworms increased pasture yields by 20–75% at Rushy Lagoon in northeast Tasmania and 20–35% at Woolnorth in far northwest Tasmania (Temple-Smith *et al.* 1993). Earthworms are not considered to be adversely affected in soils with pH_w > 5.0 (Garnsey 1993) although liming was advocated to increase soil pH_w to 5.8 to ensure that worms thrive and breed (Farquhar 1992).

(iv) Powdered limestone is frequently added to stock feeds as a source of calcium particularly when feed is to be consumed by laying hens (Bruce 1976).

CONCLUSIONS

This review records the many roles that agricultural lime has played in the development of Tasmanian pasture and crop production between 1940 and 2020. These results provide the foundations that underpin current and future use of liming materials with the knowledge being integrated into current farming practice.

Liming has increased yields in vegetable, medicinal, pasture and forage crops grown on Krasnozems (Ferrosols). It also improved pasture production and yields of cereal and pulse crops grown on lateritic podzols (Kurosols). Similarly, liming increased fruit and pasture yields on yellow podzolics (Kurosols). It was also vital in the establishment of nitrogen fixing pasture legumes on Podosols, Ferrosols and Kurosols. All these soils lie predominately in areas where annual rainfall exceeds 750 mm.

Mechanisms underlying the responses have been attributed to increased supply of calcium and magnesium and increases in soil pH. Increases in pH improve survival of rhizobia, nodulation and nitrogen fixation capacity of legumes, increased availability of phosphorus and molybdenum and reduced manganese, aluminium and cadmium availability as well as phosphorus leaching. Notwithstanding identification of these mechanisms as primary limiting factors on some soils, other factors may be contributing to the effects although at a lower or immeasurable level. In some instances, these factors may not even be recognised, let alone considered.

Applications of lime will continue to be applied in Tasmanian agriculture as maintenance dressings to neutralise soil acidification and maintain yield responses that produce an economic return over the long term. However, risks of over-liming cannot be discounted.

Potential areas for future research

Improved soil structure and hydraulic conductivity has been reported on a Krasnozem (Brown Ferrosol) at one site (Kirkham 2003, Kirkham *et al.* 2007). The potential for liming to improve soil structure on this and other soils, particularly where permeability restricts infiltration rates and leads to runoff or sheet erosion, could be investigated.

Most responses to heavy liming in Tasmania have been recorded in areas with an average annual rainfall (AAR) above 750–800 mm. The potential of heavy liming on soils in lower rainfall areas, particularly on yellow podzolics (Kurosols) could be beneficial since these soils were acid and responsive at higher AAR levels. Any such investigation should consider whether responses to liming are being limited by macro or micro element deficiencies occurring *in situ* or induced by liming.

Future investigations into the movement of lime in soil profiles need to recognise that movement is slow (years) and account needs to be taken of horizontal as well as spatial variability. The rate of movement down the profile does not seem to be dominated by the rate of application and is probably influenced by pH-dependent cation exchange capacity. Furthermore, it cannot be assumed that nominal depth of incorporation reflects reality. Consequently, vertical sampling segments should be relatively small (25–50 mm). Another consideration would be to use very fine lime to eliminate particle size effects on the rate of dissolution of limestone particles.

The amount of agricultural liming materials applied within each of Tasmania's three Natural Resource Management (NRM) areas was calculated to be more than 1.6 times the amount of lime required to neutralise the acidifying effects of annual applications of nitrogen fertiliser within these areas (Rowe 2023). This suggests that more than sufficient lime is being used to neutralise acidification, not only by nitrogen fertilisers, but other sources of soil acidification such as atmospheric sulphur and product removal. However, more detailed analyses at an enterprise or property level would be required to confirm that sufficient lime is being applied to account for all sources of soil acidification.

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CELEBRATING WITH THE NATION: ARTWORK FROM THE ROYAL SOCIETY OF TASMANIA TOURS THE COUNTRY TO MARK THE COMMONWEALTH OF AUSTRALIA JUBILEE IN 1951

by Mary E Koolhof

(with three plates)

Koolhof, ME (2024). Celebrating with the nation: artwork from the Royal Society of Tasmania tours the country to mark the Commonwealth of Australia Jubilee in 1951. *Papers and Proceedings of the Royal Society of Tasmania*. 158: 39–42. ISSN: 0080-4703. Royal Society of Tasmania, GPO Box 1166, Hobart, Tasmania 7001, Australia. Email: admin@rst.org.au

Two paintings from the Royal Society of Tasmania (RST) Art Collection were selected for an exhibition held in 1951 to celebrate the fiftieth anniversary of the establishment of the Commonwealth of Australia. The Jubilee Exhibition of Australian Art comprised 156 works chosen to represent the best of Australian art from Aboriginal art through early colonial times to the latest contemporary art. The exhibition was noteworthy for recognising the artistic merits of Aboriginal works rather than focussing on their anthropological aspects. Paintings selected from the RST Art Collection in Hobart were FG Simpkinson de Wesselow's *The Derwent from the Observatory* and *Geelong, Australia Felix, January 1847*, two of 208 artworks gifted by the artist to the RST in 1900. Touring to every state capital, the exhibition was greeted with critical appreciation and popular acclaim.

Key Words: Royal Society of Tasmania, art, Aboriginal art, Simpkinson de Wesselow, Australia, Commonwealth, Jubilee Exhibition, Laurence Thomas.

The year 1951 was filled with festivities in Australia: bonfires, fireworks and military parades; historic plays and pageants; religious and cultural festivals; and athletic and sporting tournaments. All this was to celebrate the fiftieth anniversary of the establishment of the Commonwealth of Australia – a single federated nation, with Queen Victoria's signature on the Royal Assent. The occasion was equally important for the six Australian states, which 'matured from colonies into sovereign statehood' (*The Queensland Times*, 28 Nov. 1950, p. 7).

Expectations for the Jubilee year were very high, and national pride was evident:

> *There will be entertainment on an unprecedented scale, but mainly the appeal will be to our patriotism. We can expect to be stirred by picturesque spectacle and significant pageantry. We shall hear great music and noble speeches. We shall applaud the exploits of famous Australians in the fields of statesmanship, the arts, sciences, war and athletics. We shall be invited to look back upon the storied past and cast our eyes forward into the hidden future.* (*The Sunday Herald*, 31 Dec. 1950, p. 6)

The celebrations, however, came with the high price tag of £350,000, approximately $18,000,000 in today's terms (RBA 2024).

The aims of the Jubilee celebrations were more nuanced than a simple expression of nationalistic fervour. National coordinator Lieutenant-General Berryman intended the Jubilee year to transcend parades, flag-waving and fine speeches. He was convinced this was an opportunity to progress important national themes: the assimilation of New Australians, conservation of natural resources, decentralisation of population and industry, and strengthened national defence supported by increased production (*The Queensland Times*, 28 Nov. 1950, p. 7). It was evident that a growing pride in Australian culture was developing as during a meeting of the Society of Women Writers in Sydney, the speaker pronounced it 'shocking' that the Greek tragedy *Medea* had been selected as a Jubilee play rather than something Australian *(The Bulletin,* 2 May 1951, p. 22).

A special exhibition of Australian art was planned to include a selection of the best Australian paintings chosen from the leading art galleries and private collections in the country. It was feted as 'the finest assembly of Australian works of art ever seen in one collection' (*The Sunday Herald*, 31 Dec. 1950, p. 6). The selectors aimed 'to show a small but good collection of aboriginal paintings and sculptures and to gather together … the best works by the best artists who have worked in this country from the time of the first white settlements to the present day' (Thomas 1951a, inside cover of catalogue).

The Prime Minister of Australia, Robert Menzies, threw his support behind the exhibition, urging galleries, museums, libraries and collectors to lend selected works to make a significant collection. Exhibition organiser Laurence Thomas from the National Gallery of Victoria visited the various Australian states in search of material. When Thomas first set out to seek exhibits for the early period of Australian art, he thought these would have to be mainly prints and drawings but discovered some paintings of excellent quality. Thomas believed most people would be surprised by the quality of artwork produced in Australia before 1856 (*The Queensland Times*, 20 Dec. 1950, p. 2). It was in this category that works from the RST Art Collection would feature.

PLATE 1 — Francis Guillemard Simpkinson de Wesselow's *The Derwent from the Observatory,* October 1847 (RST Art Collection)

Arranged in four sections, the first was Aboriginal art, described as being quite distinct from mainstream Australian art. The artistic merit of the Aboriginal works was recognised apart from their anthropological value: 'It is scarcely necessary to be aware of the totemistic or ritual significance of [artwork] *Spearing a Kangaroo*, for instance, to be able to appreciate its dynamic sense of movement and form' (*The Sydney Morning Herald*, 29 June 1951, p. 2). In his essay for the exhibition catalogue, Leonhard Adam explains some of the nuances and complexities of various forms of Aboriginal art (Adam in Thomas 1951a, pp. 5–7). The remaining sections of the exhibition were: Early Colonial Art; Art of the Middle Period; and Contemporary Art.

The exhibition was greeted very warmly by art commentators of the time:

> *Australian art, like Australian wine, is a commodity that would have an honoured place in the world – if anyone outside Australia realised that it existed in its present quantity and quality. Now the proof of its value and extent is before our eyes – and before any comprehending visitors from abroad who may be among us – in the Jubilee Exhibition of Australian Art.* (*The Sydney Morning Herald*, 29 June 1951, p. 2)

Chairman of the National Art Gallery in Melbourne, Sir Keith Murdoch, noted that the exhibition was quite unprecedented in Australia *(The Sun News-Pictorial*, 18 May 1951, p. 5*).*

The Jubilee Exhibition of Australian Art contained 156 artworks. Of these, two were selected from the RST Art Collection in Hobart: Francis Guillemard Simpkinson de Wesselow's *The Derwent from the Observatory* was number 63 in the catalogue, and *Geelong, Australia Felix, January 1847* by the same artist was number 64 (Thomas 1951a, p. 33). De Wesselow was described in the catalogue as 'a watercolour artist of considerable merit' (Thomas 1951a, p. 33). Two works from the Tasmanian Museum and Art Gallery were also included: John Glover, *My Harvest Home*; Thomas Griffith[s] Wainewright, *Portrait of Mrs. Wilson*; and three from the Queen Victoria Museum and Art Gallery in Launceston: Benjamin Duterreau [Duterrau], *Sullivan's Cove, 1839*; John Glover, *On the Tamar*; and John Skinner Prout, *Break of Day*.

While some commentators of the time considered the early colonial art section of the exhibition to be of 'historical rather than artistic interest' (*The Sydney Morning Herald*, 29 June 1951, p. 2), the noted Tasmanian artist Max Angus AM, FRSA, more recently took a different view of de Wesselow's work:

> *There is a quality of naturalness in Simpkinson's watercolours that makes them deceptively ordinary in appearance. They are never forced, dramatised or exaggerated, yet nothing can quite explain the extraordinary sense of freshness and vitality that comes to us across almost a century and a half.* (Angus 1984, p. 61)

PLATE 2 — Francis Guillemard Simpkinson de Wesselow's *Geelong, Australia Felix,* January 1847 (RST Art Collection)

De Wesselow's painting *The Derwent from the Observatory* looks upriver across what is now the Royal Tasmanian Botanical Gardens. This work is of particular interest to students of Tasmanian history, as it shows something of the buildings of the Rossbank Magnetic Observatory, where Simpkinson worked; the surviving buildings of the observatory are now within the grounds of Government House, Hobart. Of *Geelong, Australia Felix*, Max Angus observed:

> *The delicate watercolour painting of Geelong itself is notable for its clear light and atmosphere, further enhanced by Simpkinson's decision to leave the foliage of the larger group of trees unpainted, their forms indicated only by pencil outline. This device, often used by Turner and others, not only helps to keep the general pitch of the work in a higher key – an indispensable element in the rendering of overall light – but in this case also confines the darker tones almost entirely to the panoramic sweep of the subject, where all the interest lies, and to which the artist obviously wished to direct our attention.* (Angus 1984, p. 86)

The 1951 exhibition was the largest to have toured Australia and the first to travel the country by air. Interest was reportedly great, as it attracted crowds of the most varied kind:

> *It meant that art – and, most important, Australian art – had reached beyond the dilettante and plucked at the interest of ordinary men and women. Otherwise, why should the gallery be filled daily and often at night with apprentices and their girl friends, schoolchildren who came back to look at the pictures on their own after an official visit with their teachers, smartly-dressed girls-about-town … men in uniform, mothers with shopping-baskets and babies?* (*Pix* 1951, pp. 28–29)

Opening in Hobart on 12 March 1951 and on display there for three weeks, the exhibition then travelled to Launceston, Melbourne, Sydney, Brisbane and Adelaide, finishing in Perth. By August, when on show in Brisbane, it had been seen by 215,000 people, with Adelaide and Perth yet to come (*The Queensland Times*, 20 Dec. 1950, p. 2). 'The Exhibition … should on no account be missed', reported a reviewer following the Sydney opening (ABC, 1951, p. 26). In Perth, the art gallery opened at night to enable more people to see the exhibition (*The West Australian,* 20 Nov. 1951, p. 2*)*. Organiser Laurence Thomas noted the cultural importance of the exhibition to the nation of Australia:

> *It is not often that we can see the best works of our artists of all periods together under one roof. In this vast country we have no single artistic centre. We have no London, no Paris, no single centre to which everyone may go once in a while to keep in touch with what has been and is being done.* (Thomas 1951b, p. 26)

The Royal Society of Tasmania played a further part in the Jubilee celebrations, organising documents and pictures in the Society's possession to be shown in an exhibition in Hobart during Jubilee week, and arranging a special evening

FRANCIS GUILLEMARD SIMPKINSON DE WESSELOW, *b.* 1819

Born England. Served in the English Navy before he came to Hobart. A watercolour artist of considerable merit and a friend of Samuel Prout and Turner, whose influence appears in his work. Produced a number of watercolours in Tasmania, the majority of which are owned by the Royal Society of Tasmania.

63 THE DERWENT FROM THE OBSERVATORY
Unsigned.
Watercolour on cardboard, 9½ ins. x 13½ ins.
Royal Society of Tasmania.

64 GEELONG, AUSTRALIA FELIX, JANUARY, 1847
Unsigned.
Watercolour, 10½ ins. x 14¾ ins.
Royal Society of Tasmania.

B

PLATE 3 – (**A**) Jubilee Exhibition Catalogue cover; and (**B**) excerpt from p. 33 of the catalogue showing the two RST entries (Thomas 1951a)

at which papers dealing with Federation and Tasmanian history were read (Royal Society of Tasmania 1951).

It was an honour for the Royal Society of Tasmania to have two paintings selected for the Jubilee Exhibition, allowing these works to be seen around the country. The esteem in which the Jubilee Art Exhibition organisers held de Wesselow's art in 1951 was echoed by respected Tasmanian artist Max Angus: 'His work touched me more than that of any other of his period' (Angus 1984, p. 8), and later: 'Topographically, his watercolours are unsurpassed. His genius was to combine this with extraordinary fluency and artistic insight' (Angus 2006). The Royal Society of Tasmania is fortunate to have 207 beautiful artworks by de Wesselow currently in its Art Collection; one work from the original collection was gifted to TMAG in 1910.

ACKNOWLEDGEMENTS

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(accepted 11 August 2024)

NATURAL HISTORY OF THE TYNDALL RANGE AREA, WESTERN TASMANIA – SITE OF TASMANIA'S NEXT ICONIC WALK

by Keith D Corbett and Elizabeth (Sib) Corbett

(with five figures and ten plates)

Corbett, KD & Corbett, E (2024). Natural history of the Tyndall Range, western Tasmania – site of Tasmania's next 'Iconic Walk'. *Papers and Proceedings of the Royal Society of Tasmania* 158: 43–56. ISSN: 0080-4703. 35 Pillinger Drive, Fern Tree, Tasmania 7054, Australia (KDC* and EC). *Author for correspondence. Email: keith.corbett@bigpond.com

The Tyndall Range, approximately 15 km north of Queenstown and part of the larger West Coast Range, has been chosen as the site for Tasmania's next 'Iconic Walk', due to open in 2029. The range is composed of siliceous conglomerates and sandstones of Late Cambrian age, within which four formations are recognised. The area was glaciated in the Pleistocene and has numerous glacial features, including large and small glacial lakes, moraines and cirque cliffs. At 1,100 m altitude, it takes the brunt of the 'Roaring Forties' weather, and the influence of ice-laden winds is apparent in the wind-pruned alpine vegetation. The large area of well-preserved alpine vegetation, including deciduous beech and pencil pine forests and cushion moorlands, has escaped the many fires which have affected the adjacent slopes and lowland areas. This is highly unusual for the western siliceous mountains. The proposed route for the Iconic Walk mainly follows the more sheltered lowland area to the east of the alpine plateau, visiting the impressive Lake Huntley and several other lakes. We suggest the management status of the Tyndall area should be reviewed to reflect its significant ecological values and effectively low mineral prospectivity.
Key Words: Tyndall Range, Iconic Walk, Tasmanian glaciation, Owen Conglomerate, alpine vegetation, deciduous beech.

INTRODUCTION

The Tyndall Range area, referred to as 'the Tyndalls', is located 10 to 20 km north of Queenstown (fig. 1). It is a sub-unit of the larger N–S-trending West Coast Range, and includes the undulating lower country to the east, with several moderate sized lakes, such as Rolleston, Huntley and Margaret. The range is bookmarked by Mt Geikie in the south and Mt Tyndall to the north, with the dolerite-capped Mt Sedgwick lying just outside the area to the south. The range is rugged and scenic, with several glacial lakes and related features, and some remarkably well-preserved alpine vegetation, including deciduous beech *Nothofagus gunnii*. The Tasmanian government has announced that the next Iconic Walk will traverse the range, and this has caused some controversy mainly due to the sensitive nature of the alpine vegetation.

The Tyndalls area is contained within the Tyndall Regional Reserve, one of several reserves along the West Coast Range. The management of these reserves allows for mineral exploration and the development of mineral deposits, and the harvesting of special timber species, while also protecting and maintaining the natural and cultural values of the land under the *Nature Conservation Act 2002*.

The authors have explored the range numerous times, and the senior author has mapped the geology in his role as geologist for the Geological Survey in the 1980s. This paper outlines the geology, glacial features and vegetation of the area, and provides context for the proposed new walking track. It also comments on the management status of the area in relation to its geology and ecological values.

GENERAL DESCRIPTION

The Tyndall Range was named in 1877 by James Reid Scott, on the advice of explorer TB Moore (Baillie 2010), who continued naming the peaks of the West Coast Range after famous British geologists/scientists of the time (e.g., Murchison, Lyell, Darwin, Huxley, Sedgwick). It was named for Professor John Tyndall (1820–1893), who made important contributions to physics, atmospheric science and glacial geology.

Like most of the West Coast Range, the Tyndall area is composed of pink- to grey-coloured siliceous conglomerate and sandstone of the Late Cambrian Owen Group (about 490 Ma), generally referred to as 'Owen Conglomerate'. It is bounded to the east and west by the Mt Read Volcanics, of older Middle Cambrian age (about 500 Ma). The area was glaciated during the Pleistocene and contains many distinctive and impressive glacial features. As the first high country from the west coast in this area, the Tyndall Range is subject to the full force of the 'Roaring Forties', with gale-force winds common and often accompanied by rain and sleet. This is evident in the vegetation on the range, much of which is heavily wind-pruned. Nearby Lake Margaret and Mt Read are among the wettest places in the state, with annual rainfall of about 3,000 mm. Frequent cloud cover on the range provides another hazard for potential visitors.

The Tyndall Range rises abruptly from a flattish plain scattered with conglomerate erratics around the Henty River area (pl. 1), at an altitude of about 500 m, to an undulating alpine plateau at around 1,100 m. The plateau is 1–2 km wide and about five km long, extending between Mt Geikie in the south and Mt Tyndall in the

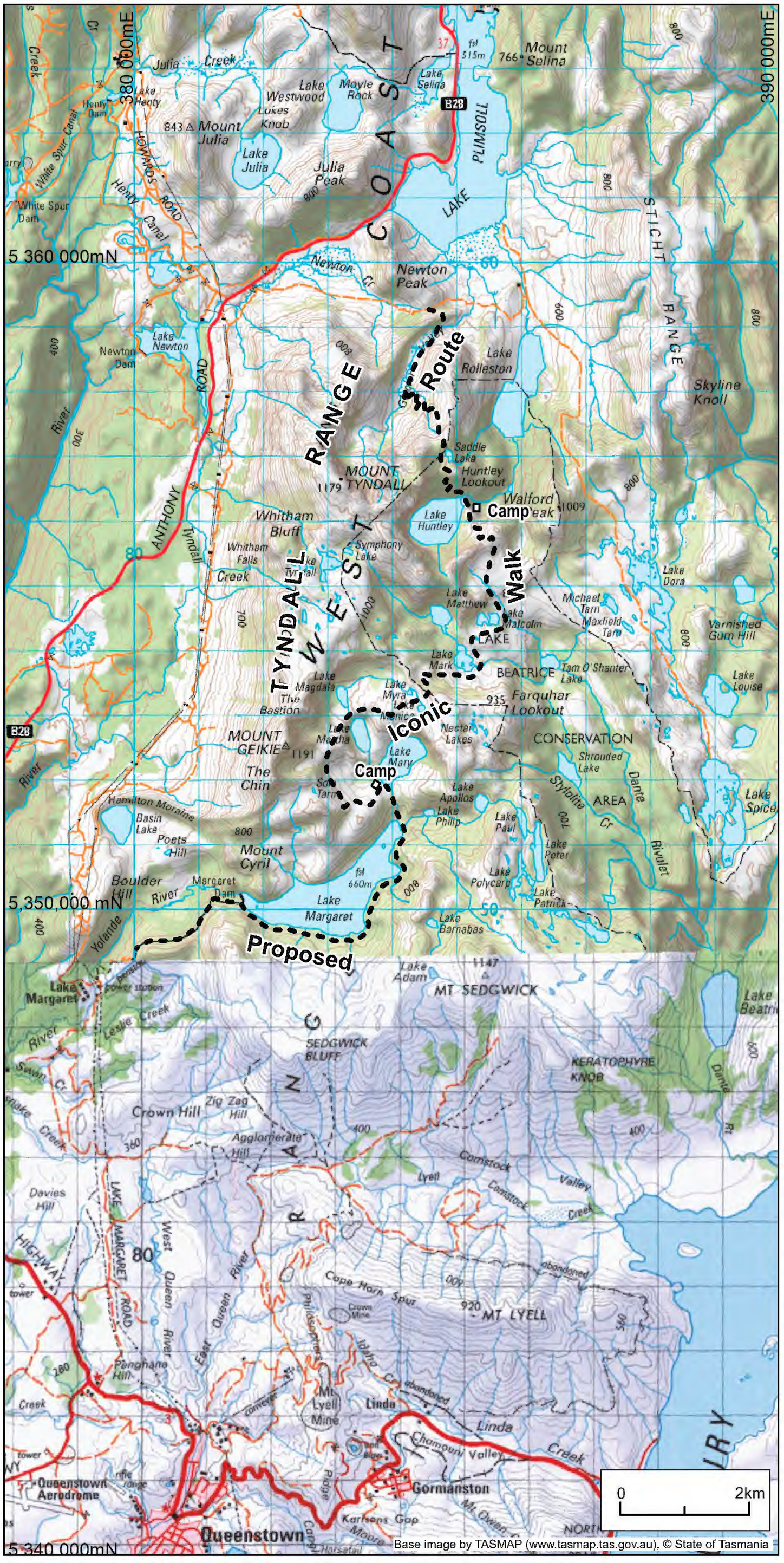

FIGURE 1 — Topographic map of the Queenstown–Tyndall Range area showing general location of proposed Iconic Walk

PLATE 1 — The Tyndall Range viewed from the NW. Whitham Bluff in middle, with trace of Whitham Fault visible. Mt Geikie on right. Glacial erratics and Lake Newton in foreground.

PLATE 2 — Tyndall plateau looking south to Mt Geikie. Lake Tyndall to right. Middle Owen Conglomerate rims foreground lake. Christine Corbett for scale.

PLATE 3 — View NW from Mt Sedgwick to Mt Geikie and Tyndall Range. Jurassic dolerite and Lake Barnabas in foreground, lakes Mary, Martha and Magdala to right. Note fire scars in vegetation.

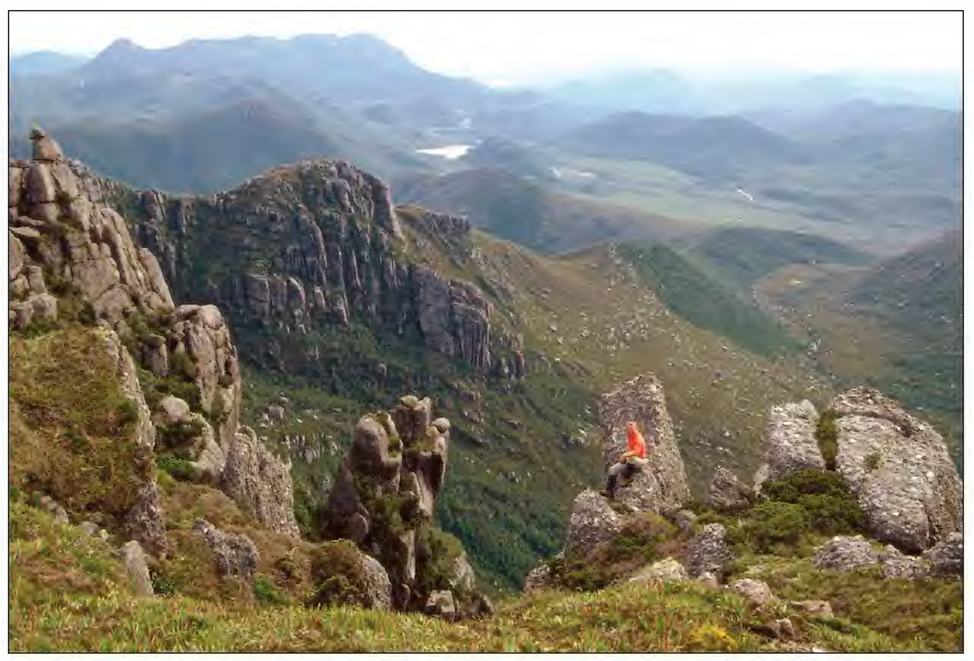

PLATE 4 — View north from Mt Tyndall to Mt Murchison, prior to filling of Lake Plimsoll. Glacier Valley to right, with forested lateral moraine. R Hargreaves for scale.

north. Small lakes and flat-lying conglomerate strata are prominent (pl. 2), as are areas of alpine moorland and low forest. The plateau narrows to the south, at Mt Geikie, and is a narrow ridge top beyond this. This southern end of the range is delineated by a steep, glacially carved scarp along its eastern side, dropping down to an undulating lower level at around 700 m with many lakes, including Magdala, Martha, Mary and Margaret (pl. 3). This area drains westwards via Lake Margaret and the Yolande River, through a prominent gap in the range marked by two large glacial moraines which project across the lower country to the west. Lake Margaret has a small concrete dam (actually two dams joined to a conglomerate outcrop in the middle), and water is collected via a wooden stave pipeline to a power station at Lake Margaret township. This scheme was built by the Mt Lyell Company in 1914 and is now operated by Hydro Tasmania.

The western side of the Tyndall Range is formed by a single continuous slope to about 600 m high, becoming steeper to the north of Whitham Bluff to form an impressive scarp of stratified conglomerate cliffs (pl. 1). Whitham Bluff forms a hump-like eminence halfway along the slope, marked by the Whitham Fault on its northern side. Tyndall Creek and a major tributary tumble off the plateau on either side of Whitham Bluff, the northern one having a belt of rainforest along it, and the southern one forming the Whitham Falls. This western scarp marks the western limit of the great conglomerate formation, which was originally controlled by a large N–S fault, the Great Lyell Fault, which is now found running along the foot of the scarp. Glacial action through the Pleistocene has also accentuated the scarp.

A major E–W swampy valley drained by Newton Creek marks the northern end of the Tyndall Range, and the Anthony Road goes through this gap to the eastern side of the main range (fig. 1). Newton Creek feeds into Hydro Tasmania's Lake Newton just to the west, and this water is pumped up to the Henty Canal, which takes water back through the gap into Lake Plimsoll on the eastern side. The four-wheel-drive Lake Spicer exploration track runs along the northern foot of the range and provides access to the eastern side of the high country and the volcanic rocks at Lake Dora and Lake Spicer. A long gentle slope climbing southwards from Newton Creek to Mt Tyndall is broken abruptly by the deep NNE-trending Glacier Valley, which has an impressive 450-m headwall under Mt Tyndall, and a large, partially wooded moraine along its western side (pl. 4). The Iconic Walk route is planned to partly follow this valley from the vehicle track.

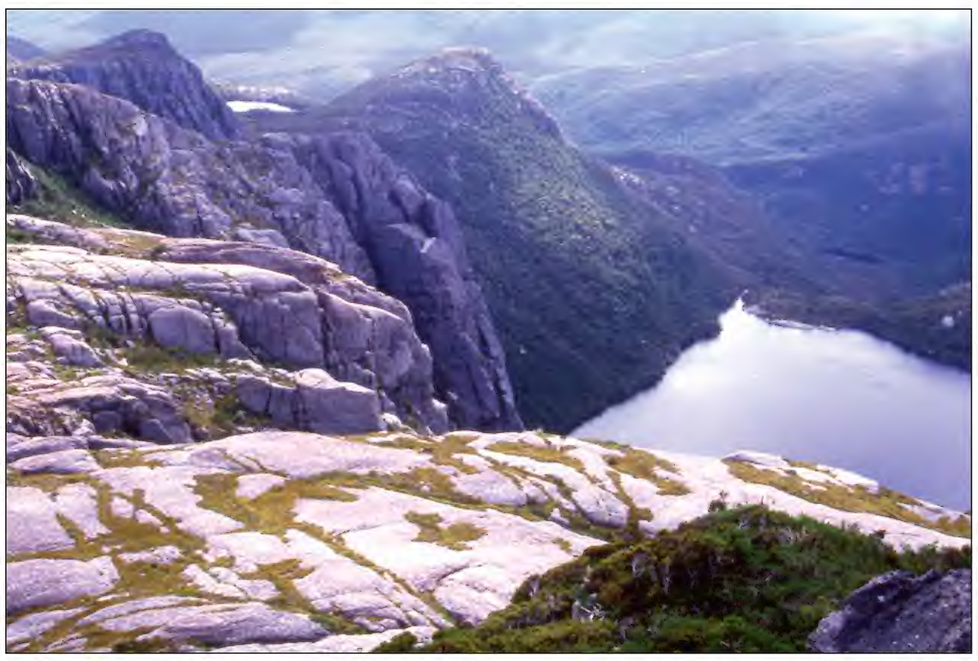

PLATE 5 — View NE from above Lake Huntley, showing ice-smoothed conglomerate. Saddle Lake and Huntley Lookout in background.

PLATE 6 — View west over Lake Huntley to the headwall cliffs in Middle Owen Conglomerate, with Upper Owen Sandstone above. This will be a highlight of the proposed Iconic Walk.

PLATE 7 — View NW over lakes Mark, Matthew and Malcolm from Farquhar Lookout, with Tyndall plateau at top left. Iconic Walk route crosses this view.

East of Glacier Valley is an irregular ridge falling to Lake Rolleston further east and becoming more rugged to the south as it climbs to plateau level east of Mt Tyndall. Two picturesque small lakes, Niche Lake and Saddle Lake, are nestled on the ridge, and it falls abruptly to the south into the spectacular cirque depression of Lake Huntley (pl. 5). This deep glacial lake is encircled to the west by 300-m-high conglomerate cliffs (pl. 6), smoothed and polished at the top by the ice which would have crashed over them during glacial periods. This view of the Huntley cliffs will be a highlight of the proposed walk. The vertical cliff face has attracted rock climbers since the 1990s and was first climbed in 2000 (Narkowicz 2021). A forested glacial valley extends below Lake Huntley to Lake Rolleston, the slope rising further east to the sharp eminence of Walford Peak, on the eastern edge of the conglomerate.

South of Lake Huntley, the Tyndall plateau falls via an irregular scarp to a broad undulating area at about 700 m altitude which continues eastwards to Lake Dora. Three small lakes (Matthew, Mark and Malcolm) are prominent on the ice-carved surface (pl. 7). A low E–W ridge with three small lakes (Myra, Monica and Nectar) culminates in Farquhar Lookout, and separates the area from that of Lake Mary country to the south. To the southeast of this, a low escarpment drops about 100 m to the SSE-trending limestone valley of Dante Rivulet, with Tam O'Shanter Lake at its head and Shrouded Lake further south. This valley drains to Lake Beatrice and to the King Valley further south.

Between the Dante Valley, Lake Margaret and Mt Sedgwick is an open rocky plateau area at 800–900 m altitude of smoothed conglomerate bedrock and small lakes, including Peter, Paul, Polycarp, Patrick, Apollus and Philip. Most of these lakes drain into Lake Margaret, with some drainage openings cleared for hydro-electric purposes in the early period of the Lake Margaret scheme. An exploration drill hole was drilled on this plateau, 1 km SE of Lake Peter, in 1988. Two small lakes, Barnabas and Adam, lie just west of Mt Sedgwick, as the country rises south of Lake Margaret to the Sedgwick Bluff area at around 1,000 m. Mt Sedgwick itself is an isolated peak of Jurassic dolerite, sitting on a thin succession of Permian tillite and mudstone, which in turn rests unconformably on the conglomerate basement.

GEOLOGY

Little geological work was done in the area until it was mapped at 1:25,000 scale as part of the Geological Survey's Mt Read Volcanics Project in the 1980s, in which the senior author was involved (Corbett & Jackson 1987, McNeill 1987). Most of this mapping was carried out from field camps at Symphony Lake, Lake Mary and Lake Rolleston, over several months. Most of the Mt Read belt, and the associated conglomerate range, between Elliott Bay in the south and Sheffield in the north, were mapped for this project over several years.

Regionally, the Late Cambrian conglomerates form a discontinuous band, 5–10 km wide, along the larger Mt Read belt near its eastern side, where the volcanic rocks are in contact with the large belt of Proterozoic quartzites. The volcanic succession is a complex mixture of lavas, intrusives, ash and fragmental deposits and volcano-sedimentary rocks (Corbett & Vicary 2014), dominated by light-coloured felsic rocks rather than dark basaltic rocks.

A unit of siliceous sandstone, conglomerate and siltstone, known as the Sticht Range Formation, sits directly and unconformably on the Proterozoic rocks at the eastern margin of the belt, and forms the base of the volcanic succession (Baillie 1989, Jago & Bentley 2022). The volcanic rocks underlie the conglomerates on the range, but at considerable depth (figs 2, 3). Some indication of the depth is given by a drill hole drilled to 600 m in the conglomerate east of Mt Sedgwick.

The conglomerate succession is known throughout western Tasmania as the 'Owen Conglomerate', although since its subdivision into four formations it is officially referred to as the 'Owen Group' (Corbett 2001, 2014; Noll & Hall 2003). In the Queenstown–Tyndall Range area, the conglomerates were deposited mainly as fluvial gravels, on large alluvial fans spreading out from highland areas of Proterozoic quartzites further east. A series of these large fans, up to 10 km wide, extended north for over 100 km from the D'Aguilar Range in the south to Mt Roland in the north – a huge expanse of white gravel unrelieved by greenery, since there were no land plants.

In the Queenstown–Tyndall Range area, the basin containing the fans had an abrupt western margin controlled by the then-active Great Lyell Fault. This large N–S fault, which runs through the Mt Lyell Mine workings and then northwards along the foot of the Tyndall Range, continued to subside as the gravel accumulated on its eastern side, resulting in a great thickness accumulating against the fault. At least 2 km thickness is present at the Mt Lyell Mine (Corbett 2001), and there appear to be similar thicknesses along the Tyndall Range (Noll & Hall 2005, Corbett 2014). The fault has been drilled in several places along the Tyndall Range (fig. 3) and at Mt Lyell Mine, and dips west at 65–70°. The various Owen formations, except perhaps the uppermost sandstone, all thin out to the east away from the fault, making this Owen basin a classic example of a half-graben (fig. 3).

A broad gentle anticlinal fold, the Tyndall Anticline, extends through the Tyndall Range area, and controls the outcrop distribution of the Owen formations (fig. 2). The fold is expressed in the arcuate outcrop of the conglomerate formations around Mt Sedgwick and near Lake Magdala and Lake Tyndall. The fold was produced during the Tabberabberan Orogeny, in the mid-Devonian, when all the older rocks in Tasmania were deformed (Williams 1978, Corbett 2019). Dips in the bedding are quite low in the central part (5–20°), reflecting the great thickness of hard conglomerate being folded, but become steeper (50–80°) to the east, in the Lake Rolleston area, where the formations are thinner and there are numerous secondary folds trending NNW to NW (Corbett & Jackson 1987). The limestone in the Dante Rivulet valley defines a larger synclinal fold on a NNW trend.

The coarse siliciclastic succession generally consists of a mixture of fine-grained conglomerate (clasts of granule- to pebble-size, i.e., 2–64 mm), coarse-grained conglomerate (clasts of pebble- to cobble-size, 4–256 mm, or cobble- to boulder-size, 64–>256 mm), and sandstone, all made predominantly of quartzite detritus. Four different formations have been recognised and mapped on the Tyndall Range, and on the adjacent mountains, within the general succession.

An upper sandstone-rich formation, referred to as the **Upper Owen Sandstone**, is dominated by pink sandstone and fine-grained conglomerate, with minor siltstone. It shows relatively thin bedding or layering, and much cross-bedding. The fine granule conglomerates are typically rich in small clasts of white chert (derived from the volcanic rocks) as well as quartzite. This unit forms the pink sandstone ridge above the massive conglomerates of the Lake Huntley cliffs (pl. 6), where a climbers' camp is located under a sandstone overhang. It also covers most of the plateau from Lake Tyndall southwards and forms the escarpment under Mt Geikie (pl. 3). It transgresses the underlying formations to the east, as they feather out and disappear, and rests directly on the volcanic rocks in the Lake Dora area. It is of the order of 400 m thick.

The basal contact of this formation on the underlying conglomerate is sharp and channeled in places and is marked by lenses and layers of dark red hematite and hematitic siltstone in places, as at Nectar Lakes. Prospectors have dug a small trench in this material near the lakes. The hematite indicates a strongly oxidising environment at the time. Sparse trace fossils, mainly worm burrows, occur on some horizons through the sandstone, indicating a shallow marine influence, and suggesting a general depositional environment at the downstream margins of large alluvial fans washing into the sea.

A formation of massive coarse-grained pebble- to cobble-grade conglomerate, pale pink-grey in colour, called the **Middle Owen Conglomerate,** underlies the Upper Owen Sandstone. It forms the cliffs above Lake Huntley (pl. 6) and outcrops through Mt Tyndall to the steep scarp to the west (plates 1, 2, 4). Glacially smoothed outcrops occur around the Nectar Lakes–Lake Mary area, and around Lake Mark (pl. 7). It consists of rounded pebbles, cobbles and rare boulders of quartzite in a siliceous sandstone matrix, with occasional interbeds of sandstone. Bedding is poorly developed.

The formation is of the order of 350 m thick around Mt Tyndall and the western escarpment, but thins rapidly to the east, being only about 75 m thick just east of Lake Huntley, and completely absent at Walford Peak. This eastwards-thinning and wedging out has also been mapped east of Mt Sedgwick. A unit of interbedded conglomerate and sandstone forms a gradational contact to the underlying Newton Creek Sandstone on the slope north of Mt Tyndall.

A distinctive succession of interbedded grey-green sandstone, siltstone and pebble conglomerate, with marine fossils in places, the **Newton Creek Sandstone**, underlies the Middle Owen Conglomerate. It is well-exposed around Newton Creek and on the slopes north and south of this, where it is of the order of 1,000 m thick. It is also present on the ridge running through Saddle Lake and Huntley Lookout near Lake Huntley, and around the eastern shores of Lake Margaret. Trace fossils are common, and trilobites have been found in the siltstones in several places near Newton Creek. There are also bryozoans and brachiopods

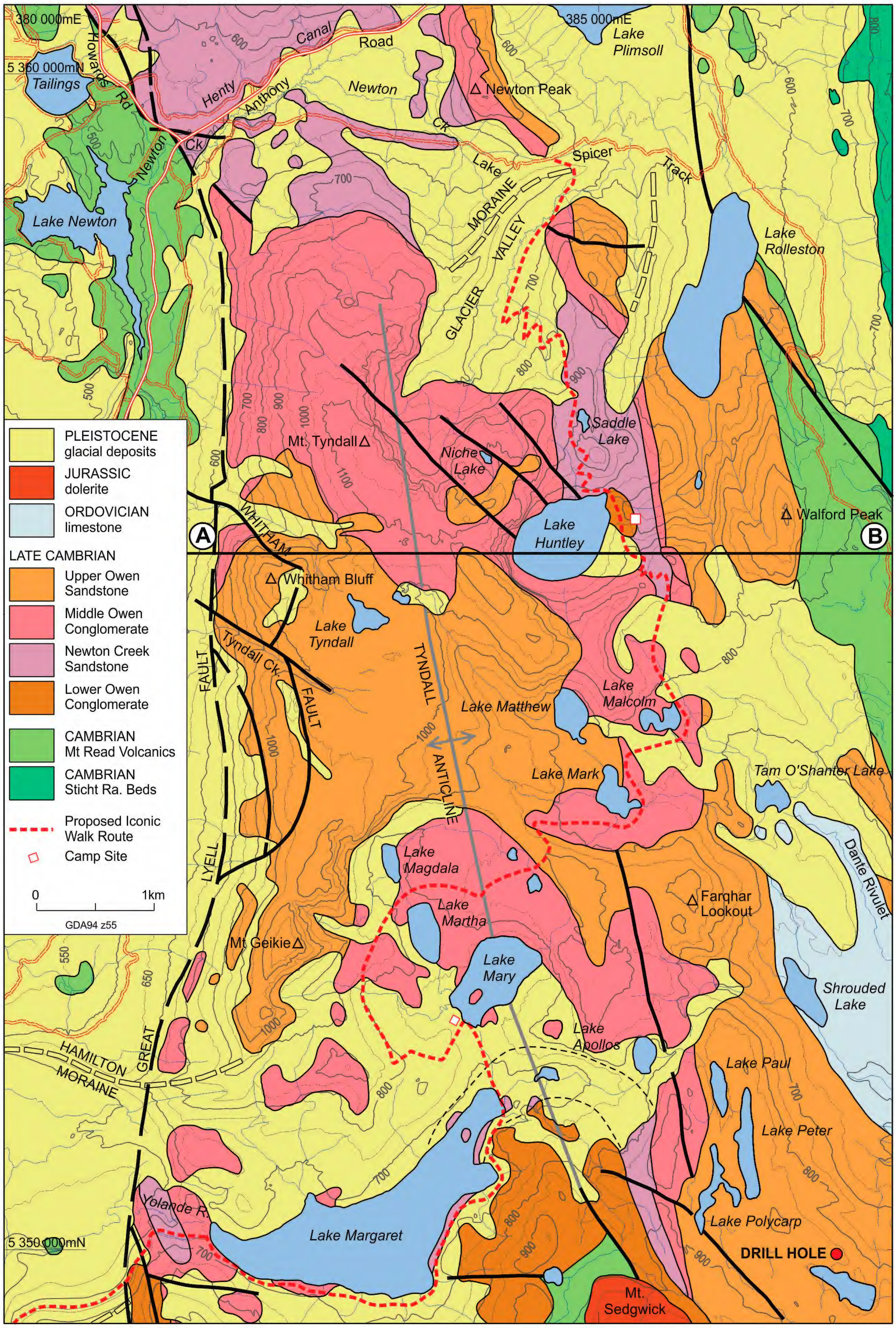

FIGURE 2 — Geological map of the Tyndall Range area, simplified from Corbett and Jackson (1987). Iconic Walk proposed route shown in red dashes.

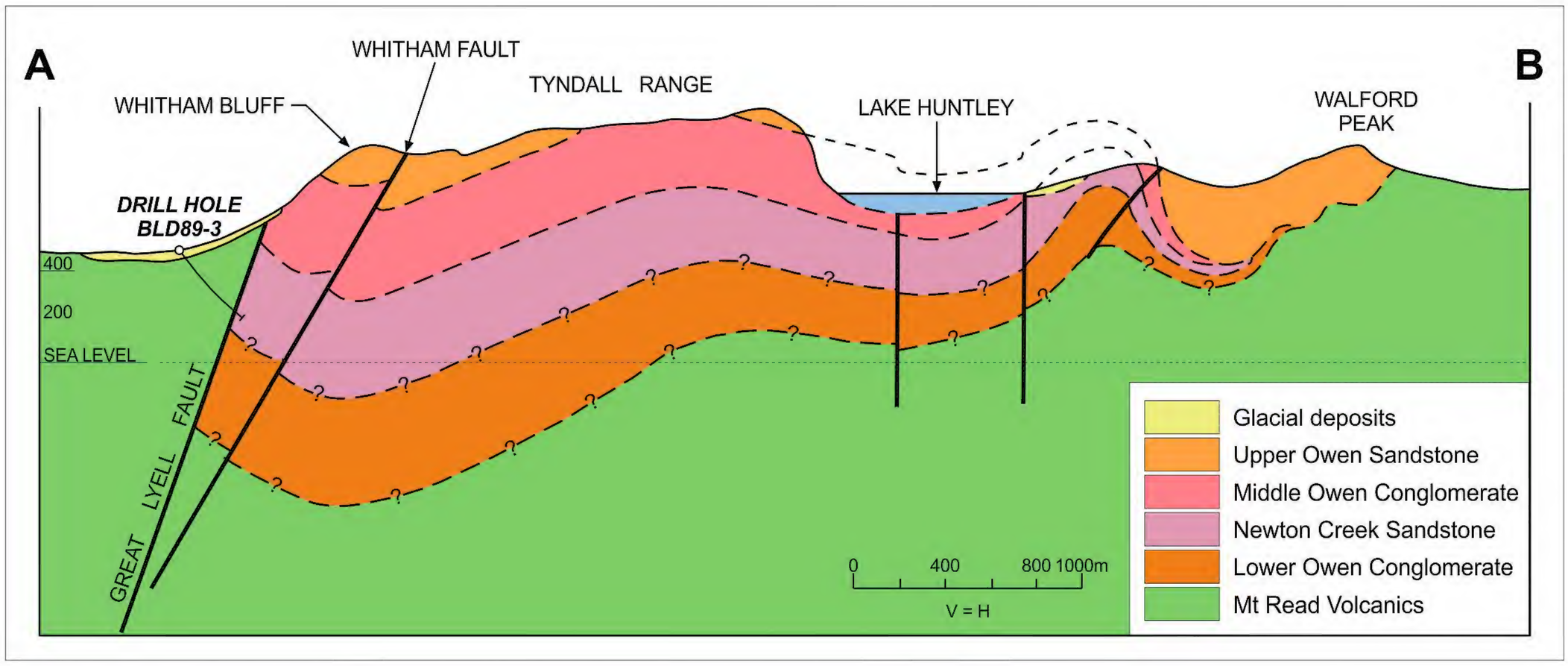

FIGURE 3 — Geological cross-section AB of the Tyndall Range. Section location shown in figure 2.

in nodular sandy limestone on the island at the NE end of Lake Margaret. The fossils indicate a Late Cambrian (late Iverian to Idamean) age (Laurie *et al.* 1995, Corbett 2014).

The formation is generally thinly bedded, and small folds are common. Sedimentary structures in the Newton Creek area include abundant graded bedding in the sandstones, slump structures, dish structures, and sole marks, all typical of proximal submarine fan deposits (Corbett 1975, 2014), while the nodular limestone at Lake Margaret indicates a shallow marine environment. Further south, on Mt Lyell and Mt Owen, the formation is represented by red cross-bedded sandstones of non-marine origin and are referred to as the Middle Owen Sandstone (Corbett 2014).

The formation represents a marine equivalent of the generally non-marine Owen sequence, deposited on a submarine fan extending seaward from the main alluvial fans, overtopping the Great Lyell Fault, and probably connecting with similar marine facies of similar age in the Dundas–Professor Range area to the west (Corbett 2014).

The **Lower Owen Conglomerate** is only seen around Mt Sedgwick and Lake Margaret in the Tyndall area, except for a glaciated outcrop at the outflow of Lake Huntley. It consists largely of thick-bedded to massive pink pebble- to cobble-grade conglomerate, like the Middle Owen Conglomerate, with a central unit of pink sandstone and a lower unit of volcaniclastic conglomerate and sandstone rich in volcanic clasts at Mt Sedgwick. The latter rests on the Mt Read Volcanics. The formation shows the pronounced eastwards thinning away from the Great Lyell Fault of the other formations and is not present at the volcanics contact to the east. It is not present in the Newton Creek area, where the marine Newton Creek facies rests directly on volcanic rocks.

Faults in the Tyndall area

The Great Lyell Fault (GLF) along the western foot of the range is mostly covered by moraine at surface, but its position is reasonably well-known from a series of diamond drill holes (e.g., fig. 3). It is offset in several places by NW-trending cross-faults, and appears to decrease in throw north of Newton Creek, where it is located within the Owen succession. Several parallel splay faults come off this fault at a shallower angle into the Owen rocks, the most obvious one being the Whitham Fault at Whitham Bluff (pl. 1; figs. 2, 3). This fault is clearly exposed on the north side of the bluff, dipping west at 40–60°, with west-side-up displacement, and can be traced about 3 km to the south, where it rejoins the GLF.

A major N–S fault affects the eastern margin of the Owen rocks in the Lake Rolleston–Lake Plimsoll area (fig. 2), and its continuation offsets the Precambrian boundary further SE. This fault postdates the Owen deposition and, like most of the other faults and folds in the area, relates to the Devonian Tabberabberan Orogeny.

The Mt Sedgwick drill hole

Drill hole 88MS1 was drilled by CRA Exploration Pty Ltd in 1988 through the Owen Conglomerate 2 km NNE of Mt Sedgwick (fig. 2, Funnell 1988). The hole was targeted on a large aeromagnetic high over the conglomerate in this area, thought to be related to a large rhyolite dome in the underlying volcanics. Such rhyolite domes, with a strong magnetic signature and some copper-gold mineralisation, are known from Red Hills to the north and from Mt Jukes and Mt Darwin to the south. Four E–W grid lines were established within the 9 km^2 Exploration License area, ground magnetic and Induced Potential surveys were conducted, and a drill rig was emplaced by helicopter.

The vertical hole was drilled to 600 m depth, but did not reach the volcanic rocks. However, the presence of volcanic clasts in the lower 150 m or so of conglomerate suggested that the hole was close to the base of the conglomerate sequence. No significant mineralisation was intersected, and no follow-up was attempted. The hole was collared in Upper Owen Sandstone and is located well to the east of the zone where the Middle Owen and Newton Creek

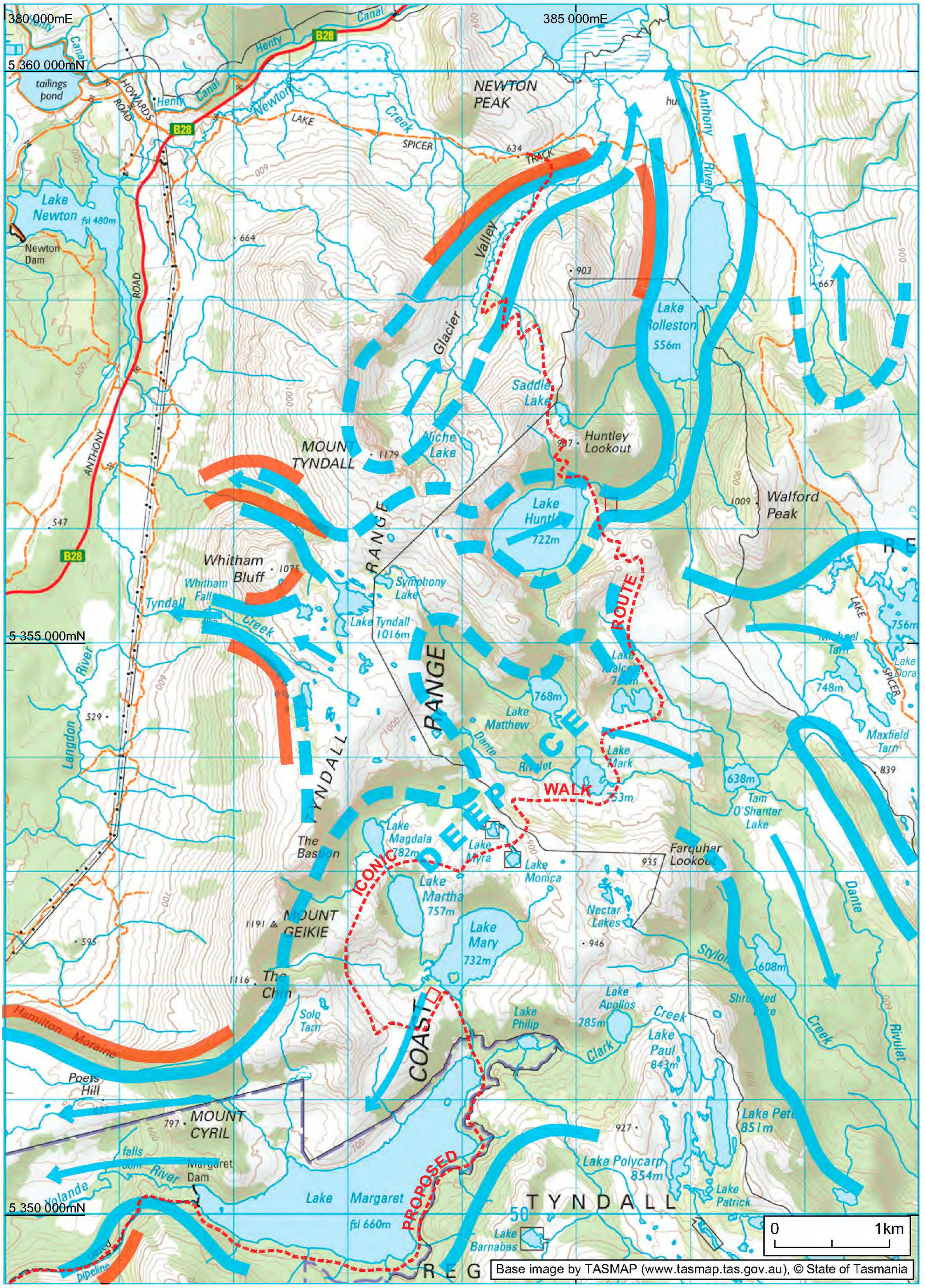

FIGURE 4 — Approximate limits and directions of flow of glacial ice in the Tyndalls area during the last Glaciation. Area of deepest ice along east edge of plateau indicated. Major moraines in brown. Iconic Walk route also shown.

formations wedge out (Corbett & Jackson 1987), so that those formations are not likely to be present. Some Lower Owen Conglomerate is likely, however. The hole penetrated some 280 m of sandstone and pebbly sandstone with siltstone interbeds (and a few beds of marly limestone), assumed to be the Upper Owen Sandstone, then some 135 m of cobble conglomerate (down to 413 m), likely to be a Lower Owen unit, then some 187 m of mainly sandy pebble conglomerate with some volcanic clasts, also likely to be Lower Owen, to the bottom of hole at 600 m.

From a regional perspective, the drill hole indicates the difficulty of exploring the possibly prospective volcanic rocks beneath such a thick cover of conglomerate. The hole is located well towards the eastern edge of the conglomerate belt, where it is likely to be relatively thin, but even here there is at least 600 m of hard conglomerate rock present. A hole located anywhere over the main part of the Tyndall Range would have to penetrate a large thickness of coarse Middle Owen Conglomerate, plus some Lower Owen, and likely to be both prohibitively expensive and impractical. The Mt Sedgwick hole was located on a distinct geophysical target – a large aeromagnetic anomaly – but did not actually reach the rhyolite dome target. Even if it had reached an interesting volcanic unit, the cost of the further exploration needed to find an orebody, if one existed, would be excessive.

PLATE 8 — View north of glaciated conglomerate slabs with glacial debris on Tyndall plateau south of Lake Tyndall. Ice has moved from right to left.

GLACIAL FEATURES OF THE TYNDALLS AREA

Glacial features such as moraines, cirques, erratics, U-shaped valleys, glacial lakes, and striated and smoothed pavements, are prominent and easy to see in the Tyndalls area. These have been known for over 100 years (see summary by Colhoun 1985) with TB Moore (1894) one of the first to write about them. Much of the discussion by early workers concerned the possible number of glacial episodes, with AN Lewis (1926, 1934, 1945) suggesting there had been three glaciations, later workers suggesting just one (e.g., Jennings & Banks 1958, Ahmad *et al.* 1959, Davies 1962, Derbyshire *et al.* 1965), and later workers, with more data and accurate dates, returning to a multi-stage interpretation (e.g., Colhoun 1984, 2014; Fitzsimons & Colhoun 1991, Fitzsimons *et al.* 1993; Kiernan 1989, 1990, Colhoun *et al.* 1996). Five Glacial periods are now recognised in places, separated by warmer Interglacial periods. Features related to the last and second-last Glacial periods (less than 200,000 years) are usually best preserved and most obvious, while those related to the oldest glaciations (> 1 million years) are generally much more extensive but more weathered and less obvious. The oldest glaciation is considered to have involved a 100-km-wide ice cap extending from the Central Plateau westwards to beyond Rosebery, probably blanketing the Tyndalls area (Kiernan 1990, Corbett 2019).

As noted by Corbett (2019), the temperature record for the Pleistocene (which began 2.6 million years ago) indicates there could have been at least 20 of these Glacial–Interglacial cycles over the past million years or so. This means that the Tyndalls area has been subjected to many glaciations, and that each glacial feature will have a multi-phase history. This is borne out by work on the large Hamilton Moraine near Lake Margaret, where dates indicate involvement by several Glaciations prior to the most recent one (Colhoun 2014). This paper focuses on the physical features to be seen at the Tyndalls, mostly related to the more recent glaciations, rather than the glacial history.

Colhoun *et al.* (1996) give a general description of the last (Wisconsin) glacial stage in Tasmania, noting that the Tyndall area appears to have been the site of a small ice cap, with ice flowing away from this in multiple directions (fig. 4). A relatively shallow thickness of ice (< 100 m?) may have been present on the plateau area, where there is clear evidence of ice flowing west from the Lake Tyndall area down the course of the present Tyndall Creek. Large areas of gently W-sloping conglomerate slabs have been cleaned and smoothed by the ice and sprinkled with bouldery till in this area (pl. 8). Two small moraines on the plateau mark the northern and southern sides of this westerly ice flow. Ice must also have flowed westwards out of the Lake Tyndall area on the northern side of Whitham Bluff, where the western slope shows two moraines, one of which is utilised by the current walking track. Ice from the Symphony Lake area probably flowed southeast.

The deepest ice, of the order of 250–300 m, would have occupied the line of cirque depressions along the eastern side of the plateau, stretching from Mt Geikie in the south around Lake Magdala into the head of Dante Rivulet above Lake Matthew and Lake Malcolm, and including the deep cirques of Lake Huntley and Glacier Valley in the north (fig. 4). This ice flowed generally east, south and north.

The major ice flow was probably to the south and southwest, via Lake Margaret, from the large accumulation area between the foot of Mt Geikie and across lakes Magdala, Martha and Mary to Lake Apollus (pl. 7). This ice exited through the gap at Lake Margaret and produced the large 100-m-high composite lateral moraine (Hamilton Moraine) to the north and west, and its equivalent to the south of the Yolande River. Hamilton Moraine is one of the largest glacial moraines in Tasmania, and grades into

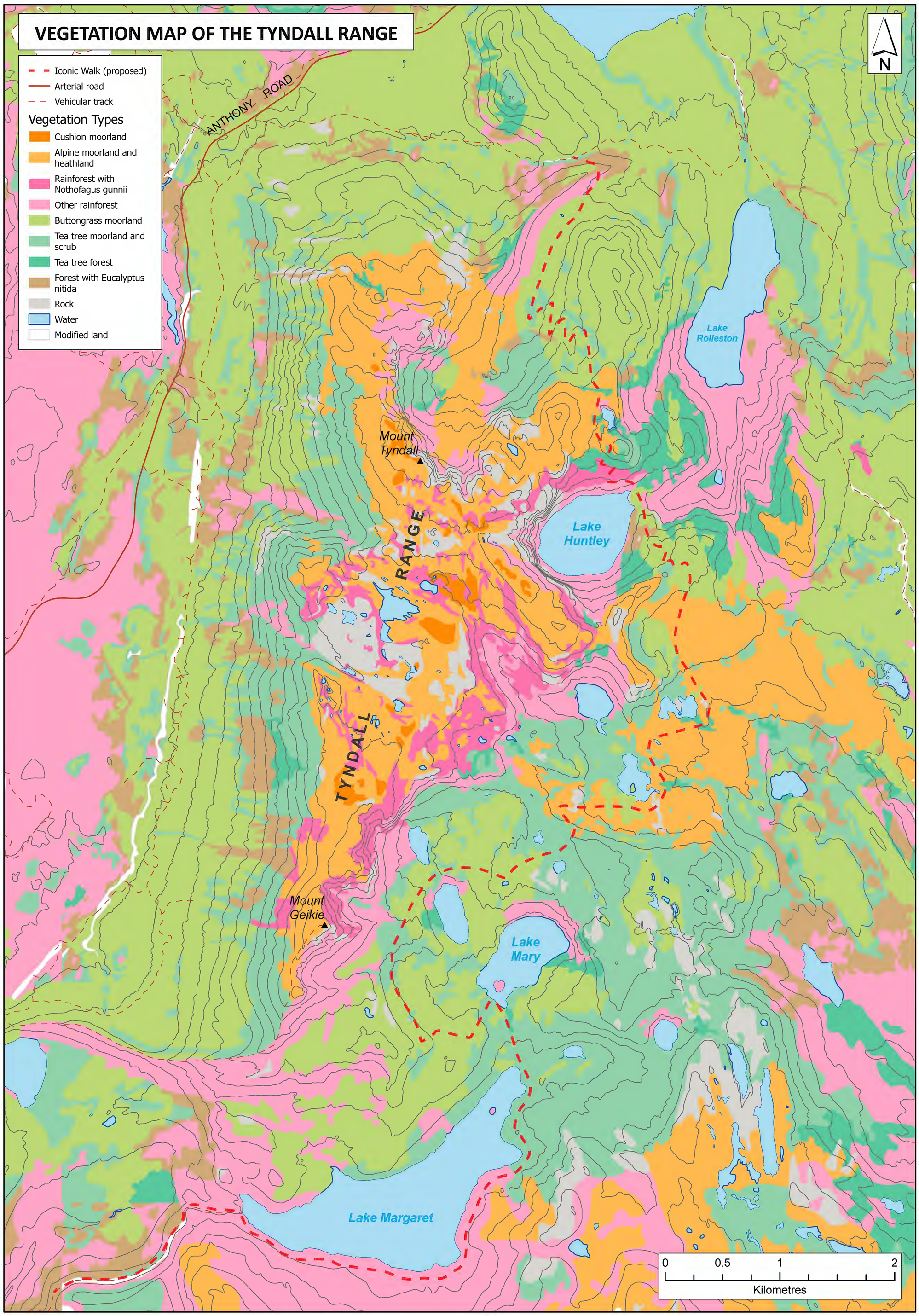

FIGURE 5 — Vegetation map of the Tyndall Range area (prepared by the TASVEG group at Department of Natural Resources and Environment, Hobart)

end moraine to the west above Lake Margaret township (Colhoun 1985, Colhoun *et al*. 1996). Boulders on this moraine have given exposure-age dates ranging from 190 to 352 kyr, suggesting that the main ridge was mainly formed during the Penultimate Glaciation, with some boulders being derived from older deposits (Barrows *et al*. 2002, Colhoun 2014).

Much of the ice from the area around lakes Matthew, Mark and Malcolm probably flowed southeastwards down the Dante Valley to the Lake Beatrice area, but some may have been confluent with ice around the Lake Dora area.

Ice from the impressive Lake Huntley cirque flowed down the now-wooded valley to Lake Rolleston and would have coalesced with ice from the valley east of Walford Peak, and with ice from Glacier Valley to the west, on the plains area of Lake Plimsoll. Extensive moraine deposits here are marked by fluting and block and tail forms (Bowden 1974, Colhoun 1985). Some ice also flowed off the plateau into the Lake Huntley cirque, smoothing and striating the conglomerate surface at the top of the cliffs (pl. 5). The deep U-shaped NNE-trending Glacier Valley has an impressive 450-m cirque headwall under Mt Tyndall and a high curving lateral moraine, 100 m high, along its western side (pl. 4).

PLATE 9 — Autumn view east over Symphony Lake on Tyndall plateau, showing areas of rainforest with *Nothofagus gunnii* and *Athrotaxis cupressoides*, and areas of open cushion moorland.

PLATE 10 — Pencil pine *Athrotaxis cupressoides* and deciduous beech *Nothofagus gunnii* at Symphony Lake showing stunted form (krummholz) and bark stripped from western side by ice-laden winds.

OVERVIEW OF TYNDALLS VEGETATION

A vegetation map for the Tyndalls area is given in figure 5, and descriptions of the many TASVEG types are given by Harris and Kitchener (2005). A general description of the vegetation on the range has been given by Kirkpatrick (1977, 1984), but much remains to be done. The map clearly shows the area of alpine vegetation on the Tyndall plateau, as defined by the combination of cushion moorland, alpine moorland and heathland, and alpine rainforest with *Nothofagus gunnii*. This area extends from just NW of Mt Tyndall to the upper slopes north and south of Lake Huntley, to Mt Geikie in the south. It is bordered to the east by a zone of 'other rainforest', i.e., mostly lacking *N. gunnii*, along the escarpment and steep slopes between Mt Geikie and Lake Huntley, and along the southern slope of the Hamilton Moraine. East of the plateau escarpments, the plains area has a mixture of buttongrass moorland, tea tree moorland and scrub, and heathland. The western and northern slopes of the Tyndall Range are dominated by buttongrass moorland and tea tree moorland and scrub, with patches of *Eucalyptus nitida* forest, all of which appear to be fire related.

Alpine vegetation

The Tyndall plateau is unusual among the western mountains in that virtually all the alpine zone is unburnt and dominated by conifers or deciduous beech (Kirkpatrick 1984). The vegetation consists largely of open alpine moorland and heathland, with large areas of bare rock, and patches of short rainforest and rainforest scrub in sheltered areas protected from the westerly winds (pl. 9). A prominent feature is the presence of espaliered shrubs of *N. gunnii* and other plants on the sheltered eastern sides of the many boulders and cliffs. Open areas of cushion moorland tend to be dominated by *Donatia novae-zelandiae*, with several other cushion species also present. There are also prostrate conifers such as *Microcachrys tetragona* and *Diselma archeri*, and small plants such as *Dracophyllum milliganii*, *Epacris serpyllifolia, Pentachondra pumila, Isophysis tasmanica*, *Astelia alpina* and *Carpha alpina*. Coniferous heaths are common, and typically include *Microcachrys tetragona* and *Diselma archeri*, with some *Athrotaxis selaginoides*.

The alpine rainforests (pl. 9) typically occur in areas sheltered from the westerly winds and show windrow development in places. They generally contain pencil pine *A. cupressoides* and deciduous beech *N. gunnii*, with King Billy pine *A. selaginoides*, *D. archeri, Richea scoparia, Orites milliganii, Richea pandanifolia*, and *Tasmannia lanceolata* commonly present. Many of the larger trees are krummholz (stunted) in form, and those at the leading edge of groups of trees commonly show stripping of bark by the ice-laden winds (pl. 10).

Much of the reproduction of the pencil pines in these harsh alpine environments is by root suckering (layering) rather than seeding, such that groups of pines tend to be clones. A study including the Tyndall Range has shown that one such group, probably near Symphony Lake (A. Darby pers. comm.), has 62 clonal stems – the largest clone reported for a root-suckering conifer (Worth *et al*. 2016).

Other rainforest

Rainforest forms an intermediate zone between the alpine flora and the fire-induced vegetation types surrounding the Tyndall Range, particularly along the eastern escarpment. It also forms a broad belt along the Henty River gorge to the west, and others along the valley of Dante Rivulet to the east, around Lake Margaret, and along the valley above Lake Rolleston. Small areas are found on fire-protected slopes at the heads of Lake Mary and Lake Martha. Although varying according to site, soil, rock type and climate, it is typically dominated by myrtle beech *N. cunninghamii*, with sassafras *Atherosperma moschatum*, celery top pine *Phyllocladus asplenifolius*, and leatherwood *Eucryphia lucida* as common associates. Scattered King Billy pine *A. selaginoides* and *N. gunnii* are present in the forests around the Tyndalls area. There is a close association with tea tree forest, (mainly *Leptospermum nitidum*) to the north and east of Lake Huntley.

Low-level moorland and scrub types

Most of the non-alpine area of the Tyndalls contains a mosaic of fire-induced vegetation types, of which buttongrass moorland, tea tree moorland and scrub are the main types, with areas of 'Tea tree forest' and 'Forest with *Eucalyptus nitida*' also present. Figure 5 shows large areas of 'alpine moorland and heathland', in the alpine area, extending east from Lake Mark and Lake Matthew, and north into Glacier Valley from Mt Tyndall. These areas are mainly 'Western alpine heathland (HHW)', and further study is necessary to clarify their composition in these areas, and the differences between the alpine and subalpine areas. It is highly unlikely that these eastern areas have not had a fire history similar to the fire-induced types adjacent to them, and their nature and classification should be checked.

The tea tree moorland and scrub vegetation include several types with both *Melaleuca* (mainly *M. squamea* and *M. squarrosa*) and *Leptospermum* species (mainly *L. lanigerum*, *L. scparium* and *L. nitidum*) as wiry low shrubs. *Banksia marginata*, *Eucalyptus vernicosa, Hakea* species and buttongrass are common associates. Tea tree forest, with tall *Leptospermum sp.*, is well-developed on the slopes east of Lake Huntley, where it forms a transitional vegetation type between rainforest and buttongrass.

Comments on fire history

The alpine flora of the Tyndall Range has survived the many fires which have clearly burnt the surrounding slopes. The western slope of the range is entirely occupied by fire-induced vegetation, particularly buttongrass and tea tree moorland, up to the edge of the plateau at about 1,000 m. The vegetation map clearly shows the finger-like fire scars of buttongrass projecting up this slope; a pattern which probably goes back to pre-European times.

There are several reasons why the fires have not continued across the plateau. The general wetness of the flattish ground, the presence of large areas of bare rock, and the general sparseness of the vegetation, are likely ones, but more research is needed. On the eastern side of the plateau, the steep cliffs of the escarpment, with the covering of rainforest, may have acted as an effective buffer for the plateau against fires.

THE PROPOSED ICONIC WALK

In 2018, the Tasmanian Parks and Wildlife Service was commissioned by the State Government to prepare a Feasibility Study for a new multi-day Iconic Walk for Tasmania, and this was released in 2021 (Parks & Wildlife Service 2021). The Tyndall Range was selected as the preferred site, and the proposed route for the three-day/two-night walking track was released (https://parks.tas.gov.au/be-involved/projects-and-programs/next-iconic-walk). This proposed route, although still subject to some variation, is shown in figures 1, 2, 4 and 5, and perhaps best seen, in relation to the topography, in figure 4. The walk is scheduled to open in 2029.

The walk begins at the Lake Spicer Track, off Anthony Road, in the north, goes partway down Glacier Valley, then climbs the slope to the east, and approaches Lake Huntley via Saddle Lake and Huntley Lookout. The first of the two hut camps is located at the eastern end of Lake Huntley. From here the route crosses open country to Lake Malcolm and then Lake Mark, before climbing the slope to Lake Myra and heading west past Lake Magdala to a second hut camp at Lake Mary. The original proposal was to follow the north shore of Lake Margaret to the dam, but a later revision takes the route around the southern shore of the lake instead. The final leg is along the existing pipeline track to Lake Margaret township. Overall, the track distance is about 28 km.

The route has been deliberately designed to follow the low country to the east of the Tyndall plateau, partly to provide some protection from the westerly weather, but also to avoid damage to the sensitive alpine area. The first section of the route will be over the large glacial moraine fringing Glacier Valley, where large erratic boulders of conglomerate are a prominent feature. This leads to a section along the flat-floored Glacier Valley for about 1 km, with views of the great rocky headwall under Mt Tyndall. A climb of about 250 m up the eastern slope brings the track to Saddle Lake, a small lake with partly forested shores. Lake Huntley is visible from here, and the nearby Huntley Lookout provides sweeping views in all directions. The bedrock formation here is the thinly bedded Newton Creek Sandstone, and some tectonic small folds are visible.

A steep descent through tea tree forest and rainforest continues to the outflow of Lake Huntley, with the view

to the 300 m cliffs at the head of the lake probably being the highlight of the walk. The cliffs, in massive Middle Owen Conglomerate, are cut by several steep cross-faults with north-side-up displacement, on the northern side. The thinly bedded Upper Owen Sandstone is visible over the top of the conglomerate. The outflow is marked by a glacially smoothed outcrop of Lower Owen Conglomerate, and the first hut camp is to be located nearby.

Leaving Lake Huntley, the route climbs a short slope of about 150 m, then crosses flat buttongrass and heathy country to the conglomerate-floored Lake Malcolm and Lake Mark (pl. 7), at the head of Dante Rivulet. A recent update shows a campground at Lake Malcolm. It then climbs the low sandstone ridge to Lake Myra and Lake Monica and crosses more buttongrass country to Lake Magdala. It then skirts the slope under Mt Geikie to the next proposed hut at Lake Mary, where there is a pleasant beach. From here, the proposed track route skirts the southern shore of Lake Margaret to the dam and water intake at its western end. This shore features some very dense wet rainforest; however, the northern shore, currently used by bushwalkers, is relatively open. A floating log of Huon pine was found by the authors at the Lake Margaret dam some years ago, but a search of the shores could find no other evidence of this species. We surmised that there may have been Huon pine growing at the original lake, but that it was inundated when the lake was dammed.

The final section of the route follows the existing wooden stave pipeline from the lake as it snakes around the conglomerate cliffs and along the moraine to the township. This picturesque section is renowned for its abundance, in season, of Christmas bells *Blandfordia punicea* and climbing heath *Prionotes cerinthoides*.

CONCLUDING COMMENTS

Botanically, the Tyndall Range is important because of the unique preservation of a large area (approximately 6 km^2) of remarkable alpine flora featuring forests and thickets of deciduous beech, pencil pines and King Billy pines, and floriferous cushion moorland. Its preservation is highly unusual among the western siliceous mountains, where most of the alpine vegetation has been destroyed by fires over a very long period (Kirkpatrick 1977, 1984). The pristine alpine flora is enhanced by its setting amongst small glacial lakes rimmed by stratified conglomerate outcrops.

The range consists of Cambrian conglomerate, part of the 'old-folded rocks' of Corbett (2019), and the scenery is dominated by tilted sedimentary strata. This is quite distinct from the Jurassic dolerite country of the two other Iconic Walks – the Overland Track in central Tasmania and the Three Capes Track on the Tasman Peninsula – in the 'middle aged rocks', where columnar dolerite cliffs are the dominant feature. The range also has an impressive array of glacial features, which will form a large part of the attraction to walkers. Glacier Valley with its huge cirque headwall, the cliffs at Lake Huntley, and the many glacial lakes along the eastern lowland, from Lake Malcolm to Lake Margaret, will make for interesting walking.

The Tyndall Range, given its significant natural features, only has low-level Regional Reserve status. This classification allows for mining and timber harvesting, presumably because of the proximity of the prospective Mt Read Volcanics both adjacent to and beneath the conglomerates. However, the knowledge we now have of the geology of the area suggests this status should be reviewed.

The drill hole near Mt Sedgwick shows at least 600 m of conglomerate above the volcanics. This hole is located towards the eastern side of the conglomerate belt, where two of the formations (Middle Owen Conglomerate and Newton Creek Sandstone) have wedged out and are not present, and the overall thickness is therefore much reduced.

Any potential drilling on the Tyndall plateau alpine area would have to penetrate at least 350 m of Middle Owen Conglomerate and probably a similar thickness of Newton Creek Sandstone and Lower Owen Conglomerate, i.e., probably a km or more of conglomerate, to reach the volcanic rocks (fig. 3). This would seem to be prohibitively expensive and impractical, considering the number of drill holes normally required to locate, define and prove up a viable mineral deposit.

Finding a target through this much conglomerate, by whatever geophysical or other means, also seems improbable.

Accessing a target from the side, i.e., coming in under the conglomerate after getting to the base in the softer volcanic rocks, would involve possibly a kilometre of shaft before a long horizontal drive, which also seems prohibitively expensive and impractical.

It is recommended that the natural values of the Tyndall Range deserve better statutory recognition and given the challenges of mineral exploration in the area, the conservation status of the range should be reviewed and strengthened. The preservation of the Tyndall alpine vegetation from fire, despite the obvious evidence of fires having burnt up the nearby slopes for a very long period, seems almost miraculous, and the area should be managed to ensure its continued survival.

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Dr Jamie Kirkpatrick first recommended the Tyndalls area to the authors in the early 1970s, and we have been visiting the area ever since. We extend our sincere thanks to the TASVEG group at Department of Natural Resources and Environment, and particularly to Lindsay Mitchell, for producing the vegetation map for figure 5 – an excellent application of the TASVEG data. We also thank Gillian Bennett for her expert drafting of the other maps and diagrams. Two anonymous reviewers are thanked for suggestions which have improved the paper.

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ENGAEUS EXCAVATOR, A NEW SPECIES OF FRESHWATER CRAYFISH (DECAPODA: PARASTACIDAE) FROM CENTRAL NORTHERN TASMANIA, WITH NOTES ON ITS ECOLOGY, DISTRIBUTION AND CONSERVATION

by Alastair MM Richardson

(with three figures and seven plates)

Richardson, AMM (2024). *Engaeus excavator*, a new species of freshwater crayfish (Decapoda: Parastacidae) from central northern Tasmania, with notes on its ecology, distribution and conservation. *Papers and Proceedings of the Royal Society of Tasmania* 158: 57–66. ISSN: 0080–4703. University of Tasmania, Biological Sciences, Private Bag 55, Hobart Tasmania 7001, Australia. Bookend Trust https://bookendtrust.au/. Email: Alastair.Richardson@utas.edu.au

A new species of freshwater crayfish, *Engaeus excavator*, is described from locations near Latrobe in central northern Tasmania. The species is identified by the elongate fingers of the propodus and carpus of the chelae, and a fringing row of tufts of long flexible setae along the ventral margin of the propodal finger in both large and small dimorphic claws. It is currently only known from two localities, where it excavates very deep burrows (>2 m) in clay soils. The original native vegetation at both localities has been cleared to grass paddocks or rough grazing. The species' persistence in such cleared habitat suggests that it is resilient, but its conservation status is unclear.

Key Words: burrowing crayfish, Engaeus, Tasmania, Australia.

INTRODUCTION

The southeastern Australian freshwater crayfish genus *Engaeus* was last revised by Horwitz (1990), who recognised 32 species. Of these, 14 species occur in Tasmania, all but two of which are endemic to the island. Later, Horwitz (1994) added a further species, *Engaeus yabbimunna*, which is also endemic to Tasmania.

Four species of *Engaeus* are currently listed as threatened under Tasmanian and Commonwealth legislation (NRE 2024). Of these, *Engaeus granulatus*, the central north burrowing crayfish, has been an issue for several developments and land management projects in recent years because its distribution and habitat coincide with primary production, rural living and major infrastructure land uses. Until recently, *E. granulatus* was assumed to occupy a core range exclusive of other crayfish species, but an additional, undescribed species has now been found within its range. This paper describes this new species of *Engaeus* collected during environmental surveys at two localities near Latrobe in central northern Tasmania.

METHODS

Specimens were examined under a binocular dissecting microscope; measurements were made with vernier callipers. The descriptions below follow the format of Horwitz (1990) and the following abbreviations are used:
OCL: length from posterior orbit to rear of carapace
AP1–6: abdominal pleura 1 to 6
P1–5: pereopods 1 to 5
TAL: abdominal length from rear of carapace to tip of telson
CTW: cephalothoracic width
DACL: length of dactyl of chela
PROPW: width of propodus of chela
PROPD: depth of propodus of chela
PROPL: length of propodus of chela

The sternal keel includes important characters for separating *Engaeus* species. It is described below in ventral and lateral view, following the descriptions provided for other species in Horwitz (1990). The lateral view describes the keel as a mountain range, with peaks, ridges and valleys, though the peaks are in fact the most ventral points.

ENGAEUS EXCAVATOR SP. NOV.
(fig. 1, pls 1–6)

Material examined

Holotype
Palmers Road, Latrobe. Deep burrows, excavated by a mechanical digger and then by hand, in silty loam over clay in grassed paddock east of road and northeast of Latrobe Creek. (41.222°S, 146.423°E). B French & A Richardson 12 February 2022. Tasmanian Museum & Art Gallery TMAG G10863 (male, OCL 24.0 mm).

Allotype
Henry Street, Latrobe. Deep burrows, excavated by a mechanical digger and then by hand, in clay in old paddock reverting to weedy scrub north of the road and Kings Creek. (41.233°S, 146.434°E). A Richardson & M Wapstra 7 July 2023. Tasmanian Museum & Art Gallery TMAG G10864 (female, OCL 29.7 mm).

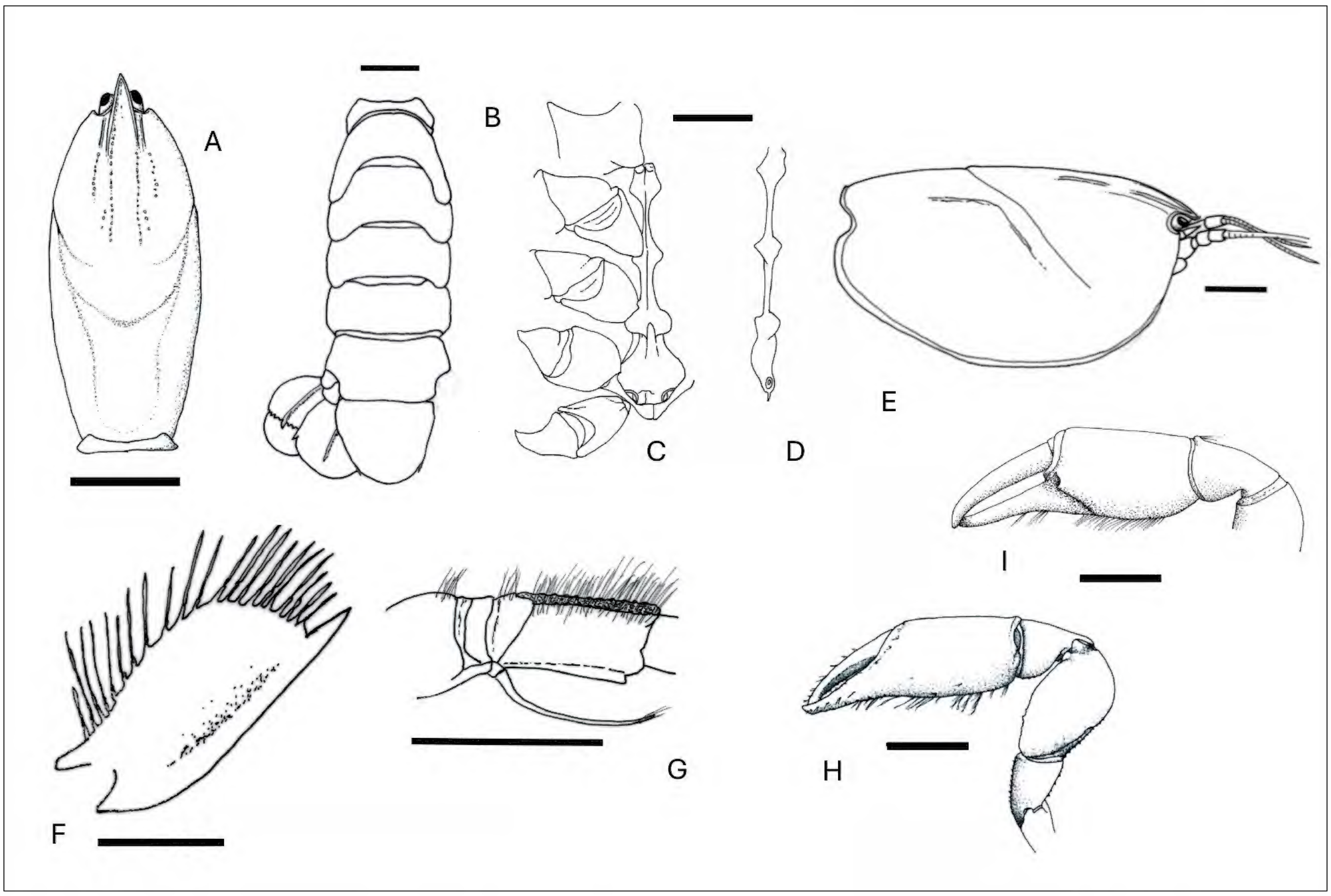

FIGURE 1 — *Engaeus excavator*. **A.** cephalothorax dorsal; **B.** abdomen dorsal; **C.** sternal keel ventral view; **D.** sternal keel lateral profile; **E.** cephalothorax lateral; **F.** antennal scale; **G.** third maxilliped, showing coxopodite, basipodite, ischium and exopodite; **H.** major chela; **I.** major chela. **A–H** from holotype, **I** from allotype. Scale bars **A–G**, **H, I**: 5 mm; **F**: 1 mm.

FIGURE 2 — Locations where *Engaeus excavator* sp. nov. has been collected. (Basemap: Google Earth).

Paratypes

Data as holotype Tasmanian Museum & Art Gallery TMAG G10865 (female OCL 25.1 mm); data as holotype Museums Victoria NMV J71458 (male OCL 21.5 mm); data as allotype Museums Victoria NMV J71459 (female, OCL 26.1 mm).

Diagnosis

Engaeus excavator differs from all other Tasmanian *Engaeus* spp. except *E. mairener* by the following combination of characters: presence of a transverse suture on the outer ramus of the uropods, the absence of a terminal spine on the posterior margin of the outer uropod, the absence (or rare presence) of pores on the lateral processes of the sternal keel at pereopod 3, and the presence of pores on the lateral processes of the sternal keel at pereopod 4 (fig. 1). It can be distinguished from *E. mairener* by the elongate fingers of the propodus and carpus of the chelae, and a fringing row of tufts of long flexible setae along the ventral margin of the propodal finger in both large and small dimorphic claws.

Description

Rostrum extending almost to distal end of penultimate segment of antennal peduncle, narrow, tip variably setose, horizontal or slightly upturned. Rostral carinae conspicuous, raised, minutely tuberculate to smooth, fading out just posterior of orbit, anteriorly not fusing with rostral rim. Intercarinate region weakly u-shaped in transverse, heavily setose anteriorly, row of setae arising from weak punctuations just mesial of each rostral carina, extending posteriorly almost to cervical groove. Sub-orbital angle blunt, slightly greater than 90°. Post-orbital ridges inconspicuous, low and blunt, asetose. Eyes small. Antennal flagella long, extending to 4th abdominal segment. Antennal scale extending to base of last peduncular segment of antenna, half as wide as long at broadest point, terminating in sharp spine; lateral margin carinate, antero-mesial and mesial margins heavily setose. Antennules bi-flagellate, inner flagellum 0.7–0.9 x outer. Inter-antennal scale approximately triangular, apically pointed or blunt. Mesio-ventral corner of third maxilliped coxopodite setose with one terminal spine and two weak spines posteriorly, ventro-lateral surface of ischium narrow, setose on all but antero-lateral surface, lateral margin carinate, terminating in small spine; exopodite longer than ischium, reaching >0.5 length of merus.

Carapace vaulted, areola 0.5 x wide as long. Carapace smooth, minutely punctate and sparsely setose, becoming granulate in mandibular and antennal regions, dorsally glabrous. Cervical groove deepest at meson, broadly v-shaped.

Abdomen 1.2–1.4 x OCL. Abdominal pleura 1 reduced, weakly bilobed, overlapped by pleura of abdominal segment 2, abdominal pleura 2–6 with sparse stiff setae. Telson tapering slightly posteriorly, terminally rounded, caudo-lateral corners with weak spine. Outer ramus of uropod with weak longitudinal median carina terminating in spine on transverse suture. Transverse suture with 4–6 spines mesially and 5–7 spines laterally, caudo-lateral corner with 1–2 marginal spines. Inner ramus with weak longitudinal median carina terminating in spine before posterior margin, caudo-lateral corner with weak spine.

Chelae isomorphic or dimorphic. Large dimorphic chela with lateral surface of propodus glabrous and almost asetose, mesial and dorsal surfaces finely granulate, granulations sometimes forming short dorsal row of small tubercles posteriorly; ventral margin of propodus with staggered row of tufts of long bristle setae, extending almost to tip of finger. Propodal finger elongate, with smooth mesial and lateral longitudinal ridges separated by setose grooves or depressions, mesial margin of finger with fine plumose setae, sometimes extending onto central mesial surface of palm. Dactyl elongate, narrow, with smooth mesial and lateral longitudinal ridges separated by setose grooves or depressions, ventral margin setose, mesial margin of finger with fine plumose setae. Small dimorphic chela like large dimorph except sometimes lacking granulation on mesial surface of propodus; dactyl with dorso-mesial row of tufts of long bristle setae, propodus with dorsal row of weak tubercles on posterior half. Carpus glabrous laterally with sparse setae, granulate dorsally, ventrally and mesially, lacking centro-dorsal depression. Merus with row of tubercles on dorsal edge, ventral surface finely tuberculate.

Sternal keel commencing after lateral processes of P1, very low between P2, rising to a blunt peak at lateral processes of P2, then falling between P3 before rising to blunt keel at lateral processes of P3, continuing to broad flat plateau at lateral processes of P4, terminating posterior to articulation of P4. Lateral processes of P1 and P2 lacking pores. Lateral process of P1 raised. Lateral process of P2 weak. Lateral process of P3 raised, setose, lacking pores, or rarely with single pore. Lateral process of P4 raised, inflated, bearing large, raised ovo-elongate pore openings postero-laterally. Bullar lobes sloping antero-mesially, separated by deep groove, posteriorly blunt.

Animals with male or female gonopores only.

Holotype male

Cephalon

Rostrum: moderately long, narrow, extending to distal end of penultimate segment of antennal peduncle, 0.11 x OCL, spineless with straight lateral margins converging to slightly upturned, bluntly-pointed tip. Whole rostrum sloping slightly downwards in lateral profile; bordered entirely by thin rim, dorso-laterally steep, weakly setose and concave between rim and rostral carinae. Rostral carinae conspicuous, straight, converging anteriorly, but fusing neither with themselves nor rostral rim, weakly tuberculate and long, 2 x long as rostral length, fading out well posterior of posterior margin of orbit. Intra-carinal region broadly u-shaped in transverse profile, becoming moderately setose anteriorly, setal row immediately mesial of rostral carinae, extending from rostral tip posteriorly almost to cervical groove. Sub-orbital angle obtuse >90°; post-orbital region slightly depressed; post-orbital ridges faint, blunt; no notch in orbital rim. Eyes small, extending halfway along rostrum.

PLATE 1 — *Engaeus excavator* sp. nov. Female. Dorsal view. Henry Street, Latrobe. (Scale bar: 30 mm) (Photo: Ryan Francis)

PLATE 2 — *Engaeus excavator* sp. nov. Female. Lateral view. Henry Street, Latrobe. (Scale bar: 30 mm) (Photo: Ryan Francis)

Antennal flagella long (tip missing), extending to 2nd abdominal segment. Antennal scale short, extending to base of distal segment of antennal peduncle 0.08 x OCL, 0.5 x wide as long, widest at distal 2/3, conical terminal spine about 0.25 x length. Ventro-lateral margin sharp, weakly setose, dorsal sub-lateral margin with rounded carina, mesial margin and antero-lateral tip with long plumose setae. Antennules bi-flagellate, flagella sub-equal 0.5 x OCL. Intra-antennal scale broad, sub-triangular, laterally rounded at base, anterior tip rounded, lateral margins slightly raised.

Ventral disto-mesial corner of third maxilliped coxa with one large and one minor tubercle, ventro-mesial margin raised, weakly tuberculate. Ventro-mesial margin of ischium with long bristle and plumose setae, plumose setae extending over posterior half of ventro-lateral face, absent on disto-lateral half. Lateral margin weakly concave, smoothly carinate, terminating in small anterior tubercle. Exopodite long, multiarticulate, shaft >0.5 x ischium, flagellum extending to 1/3 merus.

Carapace

Vaulted, 0.76 x as wide as deep, areola narrow 0.5 x as wide as long. Branchiostegites, mandibular, antennal and orbital regions of carapace minutely punctate and weakly setose, setation becoming denser ventrally. Dorsal cephalon and areola minutely punctate with sparse short setae. Cervical groove deep, broadly v-shaped at meson.

Abdomen

TAL 1.19 x OCL, AP1 reduced in width, 0.62 x CTW. AP1 with bi-lobed pleura overlapped by anterior extension of AP2 pleura. AP2–6 pleura minutely punctate with sparse setation, extending almost to dorsum on AP5–6.

PLATE 3 — *Engaeus excavator* sp. nov. Female. Anterior cephalothorax, lateral view. Henry Street, Latrobe. (Scale bar: 5 mm) (Photo: Ryan Francis)

PLATE 4 — *Engaeus excavator* sp. nov. Female. Anterior cephalothorax, dorsal view. Henry Street, Latrobe. (Scale bar: 5 mm) (Photo: Ryan Francis)

Tail fan

Telson tapering posteriorly to caudo-lateral corner bearing small spine; terminally rounded but slightly concave, dorsal surface sparsely setose, caudal margin with long plumose and bristle setae. Outer ramus of uropod with short fine bristle setae on lateral margin, low longitudinal median carina terminating in spine on transverse suture. Median suture almost straight, with 5 small spines laterally, 4 larger spines mesially. Caudo-lateral corner with two widely-separated small spines; caudal section of ramus with very faint median ridge, faint carinae radiating caudally, rear margin with plumose and bristle setae, caudal section constricted at caudo-lateral and caudo-mesial corners. Inner ramus sparsely setose dorsally, with strong median carina terminating in spine. Caudo-lateral corner with small spine, posterior margin with bristle and plumose setae. Inner and outer rami as long as telson. Uropod peduncle rounded, outer lobe setose.

Chelae

Isomorphic, elongate, minutely setose, non-granulate laterally. DACL/PROPL 0.56, PROPW/PROPL 0.28, PROPD/PROPL 0.44, PROPL/OCL 0.97. Left chela: lateral propodal palm sparsely and minutely setose, becoming weakly granulate dorsally, mesial palm weakly granulate. Ventral margin of palm with weak sub-marginal row of short bristle setae tufts, ventral margin with staggered row of long tufts of strong bristle setae. Propodal finger ventrally with extension of sub-marginal row of short bristle setae tufts lying in groove extending to distal end of finger; ventral margin of finger with row of short (or worn) tufts of bristle setae extending to distal tip, ventro-mesial row of long tufts of bristle setae. Cutting edge with 4 proximal teeth plus 4 smaller distal teeth, fine plumose setae laterally, weak granulation on proximo-lateral face. Dactyl non-granulate with dorso-lateral, dorsal and dorso-mesial rows of tufts of short bristle setae. Cutting edge with two small proximal

PLATE 5 — *Engaeus excavator* sp. nov. Female. Ventral view of sternal keel, showing inflated lateral processes and large pores of 4th pereopod. Henry Street, Latrobe. (Scale bar: 10 mm) (Photo: Ryan Francis)

PLATE 6 — *Engaeus excavator* sp. nov. Female. Major chela, mesial view, showing ventral fringe of long setae. Henry Street, Latrobe. (Scale bar: 10 mm) (Photo: Ryan Francis)

teeth, fine plumose setae laterally. Carpus asetose apart from weak setation on ventro-lateral corner. Ventral projection with single tubercle, mesial triangle granulate, becoming tuberculate posteriorly. Merus mesial surface smooth and weakly setose, dorsal margin with row of tubercles fading anteriorly; ventral surface finely tuberculate with tubercular rows on lateral and mesial margins.

Right chela: as left except propodal finger cutting edge with 3 large proximal teeth, 5 smaller distal tubercles. Dactyl cutting edge with 2 proximal teeth and 3 well-spaced distal tubercles.

Sternum

1st P: keel absent between LP, commencing as low narrow ridge, LP slightly swollen at articulations, otherwise low and rounded, setose postero-laterally, lacking pores. 2nd P: keel rising to rounded peak then falling to narrow ridge. LP weak slightly ridged, falling away steeply from keel, setose postero-laterally, lacking pores. 3rd P: keel rising to small peak, then rising again to peaked summit well above level of articulations, then falling slightly and disappearing into broad plateau between P4. LP weakly ridged, setose and lacking pores. 4th P: keel absent, LP broad, laterally raised to level of keel summit, sparse postero-ventral setation, large ovoid postero-lateral pores, pores with slightly raised rim, bullar lobes 2/3 as a long as wide, bulbous, sloping posteriorly, separated by deep central groove.

Sex

Male gonopores only, penes papilla-like, slightly raised and calcified anteriorly.

Allotype female

As for Holotype male except:

Cephalon

Rostral region badly damaged, exposing eye peduncles. Inter-antennular scale elongate, lateral margin carinate, weakly concave, anterior tip rounded. 3rd maxilliped: coxa dorsal corner with 1 large, 2 minor tubercles. Ischium lateral margin: disto-lateral tubercle very weak; exopodite shaft strongly setose. Carapace 0.71 x as wide as deep, areola 0.58 as wide as long; branchiostegites, mandibular, antennal and orbital regions very weakly granulate.

Abdomen

TAL 1.4 x OCL, AP1width 0.52 x CTW. AP2–4 with uncalcified marginal flap.

Tail fan

Telson terminally smoothly rounded. Uropod outer ramus median suture with 6 (right ramus) and 7 (left ramus) lateral and 5 mesial spines, caudo-lateral spine strong. Inner rami extending just beyond telson and outer rami.

Chelae

Dimorphic, elongate, minutely setose but non-granulate laterally. Right small dimorph DACL/PROPL 0.60, PROPW/PROPL 0.24, PROPD/PROPL 0.39, PROPL/OCL 0.93. Propodal palm smooth, minutely setose, dorsal row of 9 tubercles decreasing in size distally. Mesial palm smooth with very sparse small tubercles and setae. Ventral margin with sub-marginal row of weak setal tufts, ventral margin with staggered row of strong bristle setae tufts. Propodal finger with extension of sub-marginal row of weak setal tufts each lying in a depression, ventrally with strong tufts of bristle setae, cutting edge setose without teeth but with continuous row of scale setae. Dactyl with dorso-lateral and dorsal rows of short bristle setae, dorso-mesial row of tufts of long bristle setae, cutting edge lacking teeth but setose with continuous row of scale setae. Carpus as left dimorph but smaller and with weaker granulation. Merus as left dimorph but smaller with weaker granulation. Left large dimorph as Holotype except propodal finger cutting edge with 3 proximal teeth, 6 smaller distal tubercles. Dactyl cutting edge with proximal 3-tuberclate tooth and 9 distal tubercles reducing in size distally.

Sternum

Sternal keel: 2nd P keel rising to a higher peak; 3rd P rising to a lower, broader peak, LP more strongly ridged; 4th P keel extending as low broad ridge onto LP, LP pores strongly raised, robust rim, pores anteriorly truncate.

Sex

Female gonopores only. Right gonopore raised, left lacking raised perimeter, both with strong setation anteriorly.

Morphological variation

While there are insufficient specimens to assess morphological variation, there are some differences in the shape of the major chelae between specimens, particularly in the length and shape of the dactyl and propodal finger, which are longer and narrower in larger specimens. One specimen from Palmers Road showed a single, lateral slit-like pore on one of the lateral processes of pereopod 3.

Etymology

The specific epithet refers to the exceptionally deep burrows constructed by this species, and the machines that were required to collect specimens. It is derived from Latin *ex-* 'out' and *cavare* 'to hollow', thus *excavator*, 'one who hollows out'.

Relationship to other species

Following the identification key of Horwitz (1990) *E. excavator* would terminate with *E. mairener* at couplet 11, or in the case of the single specimen that showed a pore on one of the lateral processes of pereopod 3, with *E. mairener* at couplet 30, since sternal pores on the lateral processes of pereopod 3 are seen occasionally in *E. mairener* (Horwitz 1990). It can be distinguished from *E. mairener* by the elongate fingers of the propodus and carpus of the chelae, and the presence of a fringing row of tufts of long flexible setae on the ventral margin of the propodal finger of major

and minor chelae. Otherwise, *E. excavator* is morphologically like *E. mairener, E. granulatus* and *E. nulloporius*, which Horwitz *et al.* (1990) suggest form a clade.

Life history notes

None of the females examined were carrying eggs or young. The female specimens showed the uncalcified flap on abdominal pleuron 2 (also weakly on pleura 3 and 4) that Horwitz (1988) identified as a secondary sexual characteristic of mature female *Engaeus* species. Since this feature was present on the smallest female (OCL 25.1 mm) sexual maturity in this species must be attained below that size.

DISCUSSION

Ecology

The only other species of crayfish found sympatrically with *E. excavator* was *E. mairener.* Multiple burrows of *E. mairener* were found along a channelised section of Kings Creek bordering the Henry Street site, all of which were type 1b burrows (Horwitz & Richardson 1986), i.e., with some entrances under water at the edge of the creek. In contrast, *E. excavator* burrows were type 2, which derive their water supply from groundwater. At the Palmers Road site in January 2022 the water table was around 2 m below the surface, whereas at the Henry Street site in July 2023 some surface water was present. Soils at both sites were heavy clay.

Burrows of *E. excavator* were very deep compared to those of other Tasmanian burrowing crayfish: four of the five specimens were obtained with the use of an excavator, and the basal chambers of the burrow systems had not been reached at depths of over 2 m (pl. 7). The only hand-excavated specimen was found at about 1 m depth, well above the bottom of the burrow. Given the heavy nature of the substrate and the necessary use of a mechanical excavator, it is difficult to give any detailed description of the burrows. They seemed to have 2–4 entrances, often marked with a chimney of pellets, and tunnels that descended more-or-less vertically, with few branches.

Both *E. excavator* sites have been previously cleared of native vegetation. At Palmers Road the vegetation is exotic pasture grasses and sedges, while at Henry Street the vegetation is dominated by gorse *Ulex europaeus*, and ubiquitous pasture grasses and herbs, with native plant species restricted to scattered herbs and sedges. This raises the question of what native vegetation community the species might occur in now or occurred in before European settlement.

The original native vegetation at both sites was most likely black gum *Eucalyptus ovata* forest and woodland (TASVEG code: DOV, Kitchener & Harris 2013). Less disturbed vegetation adjacent to the Palmers Road and Henry Street sites gives an indication of how this vegetation type might have been expressed. *E. ovata* would have been the dominant canopy species, with occasional *Eucalyptus amygdalina* black peppermint and *Eucalyptus viminalis* white gum. Since European settlement, this vegetation type has been heavily modified by grazing, burning and other activities so that many occurrences, including those within the potential range of this new species, are little more than remnant canopy trees over pasture grass and weeds (M Wapstra, pers. comm.).

Distribution and conservation

Engaeus excavator is known only from the Palmers Road and Henry Street sites, near Latrobe in north-central Tasmania, which are less than 2 km apart (fig. 2). Both sites are flat or gently sloping paddocks on heavy clay soils. Similar topography exists along the Bass Highway between Dooleys Hill and Staggs Hills, and to the west on the flats surrounding Latrobe and the Mersey River, within an area bounded by the 40 m contour (fig. 3). *E. excavator* may occur in heavy clay soils in this area, but much of this area is made up of paddocks and grazing land. The earliest available historical aerial imagery shows that the Palmers Road site was a cleared paddock in 1953; the Henry Street site was at least partly cleared at that time and was fully cleared by 1977. This suggests that paddocks in the area should be checked for the presence of burrows. However, because of the very deep burrows created by *E. excavator*, and the likely reluctance of landowners to allow major excavations in their paddocks, establishing its actual range will be very difficult. However, recent studies (Dawkins *et al.* 2024) suggest that eDNA can be recovered from the chimneys of crayfish burrows, which offers significant potential for establishing the ranges of burrowing crayfish without destructive sampling.

A rough estimate of colony size can be made at each known site. Over 180 burrow entrances were recorded at Palmers Road and 150 at the Henry Street site (author's unpublished data); assuming all burrows are occupied by a single adult, and that each burrow system has at least two entrances, it is likely that each site supports fewer than 100 mature crayfish. However, without any data on the extent and area of occupancy of this new species, any assessment of its conservation status, beyond an informal assessment as data deficient, is difficult. It is worth noting that the new species persists in (and to date has only been found in) highly modified habitats (i.e. paddocks) suggesting that vegetation clearance *per se* is not a threatening process. Identifying threatening processes would need to form part of any formal assessment of its conservation status. Such threats might include large-scale habitat modification, such as extensive and deep excavation to improve pasture drainage, or for roads, dams and buildings. Without data about its current extent of occurrence, area of occupancy and abundance, it is impractical to estimate changes to such threats since European settlement or in more recent decades (i.e., the 20- and 50-year periods used under IUCN criteria).

If this species is associated with *E. ovata* forest and woodland (TASVEG code: DOV), this, in theory, affords it some protection through the forest practices system or local government planning, since this native vegetation community is listed as threatened on Schedule 3A of the Tasmanian *Nature Conservation Act 2002*. This community

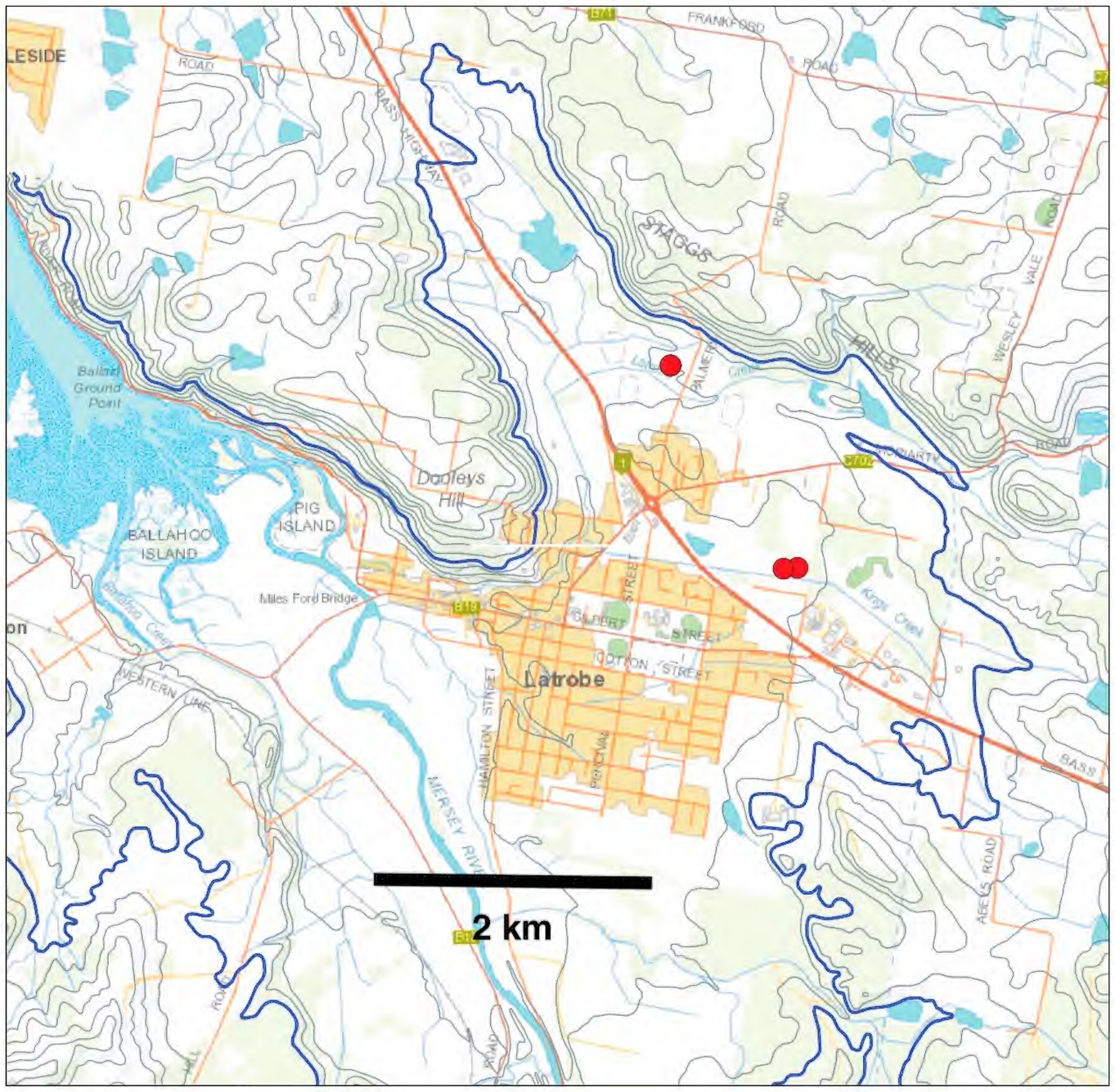

FIGURE 3 — The landscape around Latrobe, Tasmania, with similar characteristics (low, fairly flat topography, largely cleared for grazing) to the two sites (red dots) where *Engaeus excavator* n. sp. has been found. The blue line represents the 40 m contour. (Basemap: Land Information System Tasmania. https://data.thelist.tas.gov.au/).

PLATE 7 — Investigating a burrow of *Engaeus excavator* sp. nov. at the Palmers Road site, 12 January 2022. The burrow extended below the excavated depth of about 2 m. (Photo Brian French)

also equates to a threatened ecological community (Tasmanian Forests and Woodlands dominated by Black Gum or Brookers Gum) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Again, this may afford the species some protection, although only if certain threshold criteria are met in terms of extent, condition, structure and composition.

An associated conservation matter concerns the identification of burrows of *Engaeus granulatus*, the central north burrowing crayfish. This species is listed as Endangered under both the Tasmanian *Threatened Species Protection Act 1995* and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*, and its presence has triggered land management issues in several areas, e.g., along the rail corridor through Spreyton, flood mitigation measures on Kings Creek in Latrobe, etc. Distribution records to date (through the Tasmanian Government's *Natural Values Atlas https://www.naturalvaluesatlas.tas.gov.au/*) have led to the assumption that *E. granulatus* occupies an exclusive range, so crayfish burrows (at least away from the edges of its range) have been assumed to be *E. granulatus* without confirmation through excavation to positively identify the occupant. If *E. excavator* proves to be more widespread it will no longer be possible to make this assumption. The development of eDNA tools to indirectly identify the occupants of crayfish burrows is therefore urgently needed.

ACKNOWLEDGMENTS

Brian French and Mark Wapstra assisted in the initial attempts to collect specimens. Without Brian's initial manual capture of a specimen at Palmers Road, this new species might have gone unnoticed, on the assumption that these very difficult burrows belonged to *Engaeus granulatus*. I am also grateful to Rod Sherriff (Sherriff Excavator Hire) and Andrew Langmaid (Kings Creek Storage Pty Ltd.) for supplying the vital mechanical assistance. Mark Wapstra sourced historical aerial imagery and supplied information about the existing, and probable original, vegetation on the sites. I'm grateful to Brita Hansen, who prepared the taxonomic drawings and Ryan Francis for his photographs. Two anonymous referees made many helpful suggestions to the manuscript.

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(accepted 20 September 2024)

ADDITIONS TO THE TASMANIAN LICHEN FLORA FROM *ATHROTAXIS CUPRESSOIDES*-DOMINATED ALPINE VEGETATION

by Gintaras Kantvilas and John A Elix

(with two figures, seven plates and one table)

Kantvilas, G & Elix, JA (2024). Additions to the Tasmanian lichen flora from *Athrotaxis cupressoides*-dominated alpine vegetation. *Papers and Proceedings of the Royal Society of Tasmania* 158: 67–78. ISSN: 0080-4703. Tasmanian Herbarium, Tasmanian Museum and Art Gallery, Box 5058, UTAS LPO, Sandy Bay, Tasmania 7005, Australia (GK*). Research School of Chemistry, Building 137, Australian National University, Canberra, ACT 2601, Australia (JAE). *Author for correspondence: Email: Gintaras.Kantvilas@tmag.tas.gov.au.

Tasmania's *Athrotaxis*-dominated woodlands represent a distinctive habitat for lichens and support numerous remarkable species, many of which are endemic to Tasmania and confined to this host tree. In this paper, four further species known only from Tasmania are described as new to science: *Amandinea athrotaxiphila* Elix & Kantvilas, *Catinaria macrospora* Kantvilas, *Pertusaria comminuta* Kantvilas and *Pertusaria tasmanica* Kantvilas. A fifth species, *Xerotrema megalosporum* Sherwood & Coppins, hitherto known only from the cool temperate Northern Hemisphere, is recorded for Tasmania (and the Southern Hemisphere) for the first time. The presence of *Caloplaca ferruginea* (Huds.) Th.Fr. in Tasmania, previously based on a doubtful, historical record, is confirmed. All species are described in full and illustrated, and salient features of their ecology, distribution and related species are discussed.

Key Words: *Amandinea*, *Caloplaca*, *Catinaria*, conifers, new lichen species, *Pertusaria*, Tasmania, *Xerotrema*.

INTRODUCTION

Alpine Tasmania represents a highly biodiverse region, not least for its remarkable lichens. Studies on Tasmania's alpine lichens over previous decades have gradually brought to light a truly noteworthy flora, which includes many taxa endemic to Tasmania (e.g., Kantvilas 1999, Kantvilas & Vězda 2000, Kantvilas & Lumbsch 2009, Fryday & Kantvilas 2012, Kantvilas 2012, Kantvilas & Jarman 2012, Kantvilas & Søchting 2013, Kantvilas 2014a, b, McCarthy & Kantvilas 2023), taxa that underline Tasmania's ancient Gondwana connections (e.g., Kantvilas 1990, Kantvilas *et al.* 2005), and bipolar taxa that illustrate the floristic similarities between Tasmania and other cold regions of the world (e.g., Kantvilas & Louwhoff 2007, Kantvilas & Gueidan 2018, Kantvilas 2023).

The composition of the lichen biota is shaped by several critical ecological factors, with rock-type being of particular importance, as it essentially divides Tasmania into two provenances: the central and eastern provenance, dominated by Jurassic dolerite, and the western provenance, dominated chiefly by Precambrian metamorphosed sediments (Kantvilas & Jarman 1991, Kantvilas 1995). Fire history and elevation are also important determinants of alpine species distribution (Kantvilas 2022). In this paper, we document six noteworthy additions to the Tasmanian lichen flora. All represent epiphytes of the endemic conifer, *Athrotaxis cupressoides* D.Don (pencil pine), a conspicuous, highly fire-sensitive tree species that occurs in small stands, copses or as isolated trees, mainly in central Tasmania.

METHODS

The work is based on the collections of the first author, accumulated over many years of exploring and collecting lichens in Tasmania's high country, and housed in the Tasmanian Herbarium (HO). Anatomical observations and measurements are based on thin, hand-cut sections of the thallus, apothecia and pycnidia, mounted in water, 10% KOH (K), Lugol's Iodine (I), ammoniacal erythrosin and/or Lactophenol Cotton Blue (LCB). Ascospore measurements are presented in the format '5th percentile–*average*–95th percentile', with outlying values in brackets and *n* signifying the number of observations. Measurements were made from sections mounted in water, except for *Caloplaca ferruginea* where sections were mounted in LCB. Routine chemical analyses were undertaken by thin-layer chromatography (TLC) using standard methods (Orange *et al.* 2010); solvent A was the preferred medium. Liquid chromatography-mass spectroscopy (LCMS) was also undertaken on extracts of *Amandinea athrotaxiphila* and *Pertusaria comminuta* by Dr Ernest Lacy, Microbial Screening Technologies, Sydney.

The species descriptions and accompanying discussions include reference to their general context with respect to related taxa. However, full identification keys are not given here, but will be published in the *Tasmanian Lichen Flora* (https://flora.tmag.tas.gov.au/about/lichens/) when the names are formally validated

PLATE 1 — Scattered copses of *Athrotaxis cupressoides* (Turrana Heights, Central Plateau).

PLATE 2 — Fire-scarred and surviving trees of *Athrotaxis cupressoides* fringing a tarn (Mt Ophel, Central Plateau).

PLATE 3 — Mature trunks of *Athrotaxis cupressoides*, showing the furrowed, fibrous bark seemingly devoid of epiphytes (Long Tarns, Central Plateau).

ATHROTAXIS AS A LICHEN HOST

Athrotaxis cupressoides (pencil pine) is a tree is of ecological significance, being highly fire-sensitive and restricted to alpine elevations, mainly in Tasmania's central highlands. Individuals are estimated to be more than 1,000 years old. Pencil pine-dominated woodlands are classified as 'open montane rainforest' by Jarman *et al.* (1994), or as '*A. cupressoides* open woodland or *A. cupressoides* rainforest' in Harris and Kitchener (2005). Although they were once relatively extensive, fires, especially since European colonisation and particularly since the 1960s, have severely reduced their occurrence, although significant remnants still occur, for example, in the Walls of Jerusalem National Park, Mt Field National Park and elsewhere on the Central Plateau. The tree species frequently also occurs as small copses or scattered or single trees in fire-protected sites, such as at the fringes of tarns (pls 1–3). These survivors can also be observed in the wider alpine landscape, usually surrounded by dead stags of fire-killed trees that indicate the historic extent of pencil pine woodlands. In more recent times, an added threat to *A. cupressoides* has emerged from a warming climate, with associated drought, susceptibility to fungal pathogens such as *Phytophthora* and increased fire risk. Small stands that have presumably died of drought in the past few years have been observed, for example, in the King William Range, and could well be considered at risk in the future, even though at present, neither the species nor the woodlands are classified formally as threatened.

Athrotaxis cupressoides is an unusual host for lichens. A mature tree typically presents fibrous, relatively unstable bark, smooth, bleached, decorticated wood, a bryophyte-

TABLE 1 — Noteworthy epiphytes of *Athrotaxis cupressoides* woodlands

Species	World distribution	Found mainly in *Athrotaxis* woodlands	Found exclusively in *Athrotaxis* woodlands	Widely distributed in other Tasmanian vegetation types
Amadinea athrotaxiphila Elix & Kantvilas	Tas endemic		x	
Caloplaca ferruginea (Huds.) Th.Fr.	Pan-temperate (?)		x	
Catinaria macrospora Kantvilas	Tas endemic		x	
Chrysothrix palaeophila Kantvilas & Elix	Tas endemic			x
Japewia subaurifera Muhr & Tønsberg	Tas, cool temperate Northern Hemisphere	x		
Lambiella hepaticicola (Coppins & Kantvilas) Resl. & T.Sprib.	Southern Hemisphere			x
Menegazzia athrotaxidis Kantvilas	Tas endemic		x	
Meridianelia maccarthyana Kantvilas & Lumbsch	Tas endemic	x		
Mycoblastus kalioruber Kantvilas	Australia inc. Tas, NZ			x
Parmeliopsis hyperopta (Ach.) Arnold	Tas, widespread in temperate areas		x	
Pertusaria comminuta Kantvilas	Tas endemic		x	
Pertusaria tasmanica Kantvilas	Tas endemic		x	
Pseudoramonia richeae Kantvilas & Vězda	Tas, NZ			x
Roccellinastrum flavescens Kantvilas	Tas, NZ		x	
Thelotrema sp.[1]	Tas endemic		x	
Topeliopsis fatiscens Kantvilas	Tas endemic		x	
Topeliopsis kantvilasii Mangold & Lumbsch	Tas endemic	x		
Topeliopsis sp.[1]	Tas endemic			
Xerotrema megalosporum Sherwood & Coppins	Tas, cool temperate Northern Hemisphere		x	

[1] Species new to science to be described in a separate study.

dominated buttress, and hard, relatively long-lived leaves. Whereas lichens can colonise all these habitats, many trees can be effectively devoid of lichens or dominated by just a few species. Thus, in general, epiphytic lichen diversity can be poor relative to that seen on other trees such as, for example, *Nothofagus cunninghamii* (Kantvilas 1988), even if the biomass of lichens can be relatively high. It is not unusual to find a single lichen species dominating one small stand or copse, whereas another might dominate a nearby copse. *Athrotaxis* woodlands also tend to be sparse and open, and do not produce shaded, permanently moist and sheltered microhabitats that *Nothofagus*- or *Atherosperma*-dominated forests produce. Although some of the lichens found on *A. cupressoides* occur widely in other forest types in high rainfall areas in Tasmania, others are restricted to this vegetation or almost so (table 1).

THE SPECIES

Amandinea athrotaxiphila Elix & Kantvilas sp. nov.

MycoBank No.: MB 885784

Similar to *Amandinea occidentalis* Elix & Kantvilas, but differing in containing atranorin and norstictic acid, and in having ascospores 16–29 × 8–11 µm, sometimes with one or two endosepta.

Type: Australia, Tasmania, W side of Middle Lake, 41°44′S, 146°23′E, 1230 m, on lone *Athrotaxis cupressoides* in alpine heathland, 1 January 2023, *G Kantvilas 5/23* (holotype—HO; isotype—CANB).

Thallus crustose, continuous, irregularly rimose, to 30 mm wide and 0.3 mm thick, white to grey-white, dull, verruculose, sorediate; soralia 0.4–1 mm wide, excavate to plane or convex, frequently with a distinct rim; soredia white, becoming discoloured or darkening with age; prothallus marginal, dark brown or black, or inapparent; photobiont cells 8–18 µm wide; medulla white, lacking calcium oxalate (H_2SO_4–), I–. Apothecia 0.2–0.5 mm wide, lecideine, discrete, roundish, broadly adnate to sessile; disc black, epruinose, weakly concave to plane or becoming weakly convex; proper exciple persistent, elevated above the disc in younger apothecia, in section 35–75 µm thick, dark olive-brown to brown-black, K–, N– in the outer part, paler brown within. Hypothecium 40–50 µm thick, brown to dark brown; subhypothecium brown-black, 120–200 µm thick; subhymenium 15–20 µm thick, pale brown. Hymenium 50–70 µm thick, hyaline, generally not inspersed but with a few, scattered oil droplets, overlain by a dark brown to brown-black, K–, N– epithecial layer 12–15 µm thick; paraphyses 2–3 µm wide, simple to sparsely branched, with apices dark brown, 3.5–5 µm wide; asci of the *Bacidia*-type, 8-spored. Ascospores initially of the *Callispora*-type, then of the *Buellia*-type, 1-septate, brown, ellipsoid to broadly fusiform, 16–*23.5*–29 × 8–*9.1*–11 µm (n = 30), becoming constricted at the septum, often curved; immature spores sometimes with one or two endosepta; outer spore-wall minutely rugulate. Pycnidia rare, black, immersed; conidia curved, filiform, 30–45 × 0.7–1 µm. (pl. 4, fig. 1)

Chemistry: atranorin and norstictic acid (minor); soralia K+ pale yellow, KC-, C+ fleeting orange, P–, UV–. The chemical composition was confirmed by both TLC and LCMS, despite the enigmatic (but consistent) spot test results that failed to yield the expected K+ yellow→red reaction that typically signifies the presence of norstictic acid. Similarly, there was no development of red, needle-like crystals (also indicative of norstictic acid) when microscope squashes of the thallus and apothecia were eluted with K. These observations are attributed to low concentrations of this metabolite in the lichen.

Etymology: The specific epithet refers to the host of the new species, the conifer *Athrotaxis cupressoides.*

Ecology and distribution

Amandinea athrotaxiphila is known only from the region colloquially referred to as 'the land of a thousand lakes' on Tasmania's Central Plateau, where it grows on the wood and bark of isolated trees of *Athrotaxis cupressoides*. However, because most thalli are small and sterile, it may well have been overlooked elsewhere. Associated species include *Austroparmelina labrosa* (Zahlbr.) A.Crespo *et al.*, *A. pseudorelicina* (Jatta) A.Crespo *et al.*, *Lecidella* sp., *Meridianelia maccarthyana* Kantvilas & Lumbsch, *Micarea peliocarpa* (Anzi) Coppins & R.Sant., *Ochrolechia xanthostoma* (Sommerf.) K.Schmitz & Lumbsch, *Ramboldia stuartii* (Hampe) Kantvilas & Elix and *Usnea oncodes* Stirt.

Discussion

The genus *Amandinea* is one of the largest groups of buellioid lichens in Tasmania, a group that has seen a steady stream of discoveries of species previously unrecorded for the island or of species new to science (see Elix & Kantvilas 2016a, b, 2020 for the more recent additions). The group is characterised by a crustose to small-squamulose thallus containing a green unicellular photobiont, 8-spored, *Bacidia*-type asci, and brown, usually 1-septate ascospores. *Amandinea* is further characterised chiefly by its filiform conidia.

In some respects, this new species resembles the Australian endemic *A. occidentalis* Elix & Kantvilas, insofar as both are corticolous, sorediate, and have relatively large, 1-septate, ellipsoid to broadly fusiform ascospores (22–30 × 9–14 µm in the latter, Elix & Kantvilas 2013a) that become constricted at the septum, and curved, filiform conidia. However, in *A. occidentalis* the soredia are diffuse and granular rather than occurring in discrete soralia, and lichen substances are absent. Although conidia have not been observed in *Buellia yilliminngensis* Elix & Kantvilas, this species is also sorediate and has similar-sized ascospores to *A. athrotaxiphila*. However, it differs in containing gyrophoric and thiophanic acids and in lacking atranorin (Elix & Kantvilas 2013b).

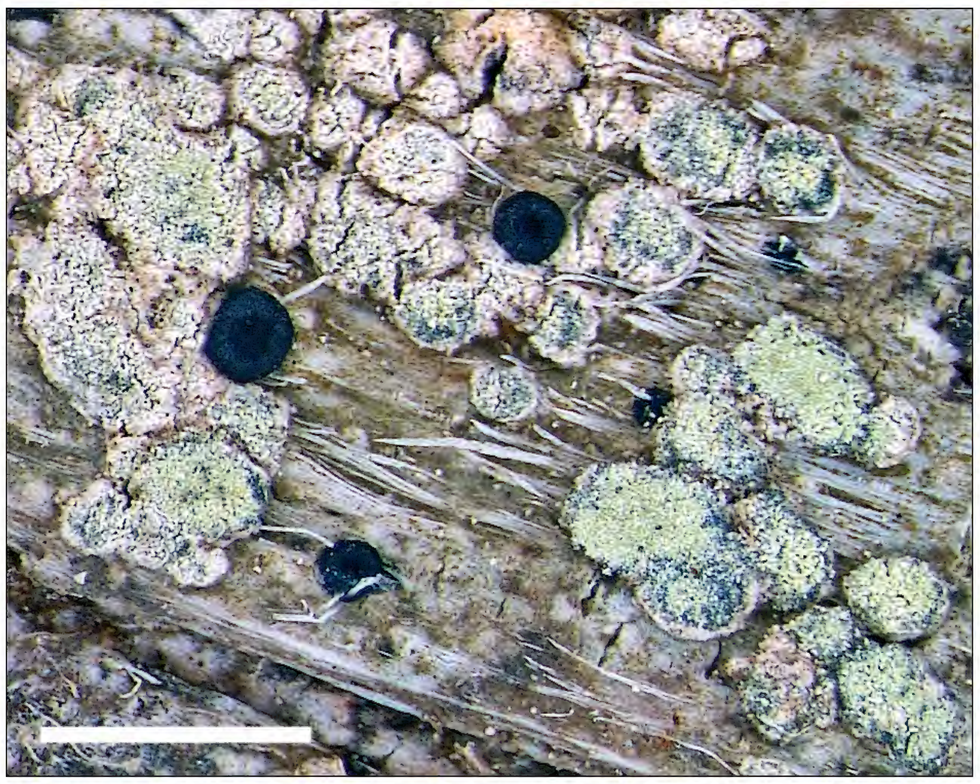

PLATE 4 — *Amandinea athrotaxiphila* with black apothecia and round soralia. Scale = 1 mm. (Photo: J Jarman)

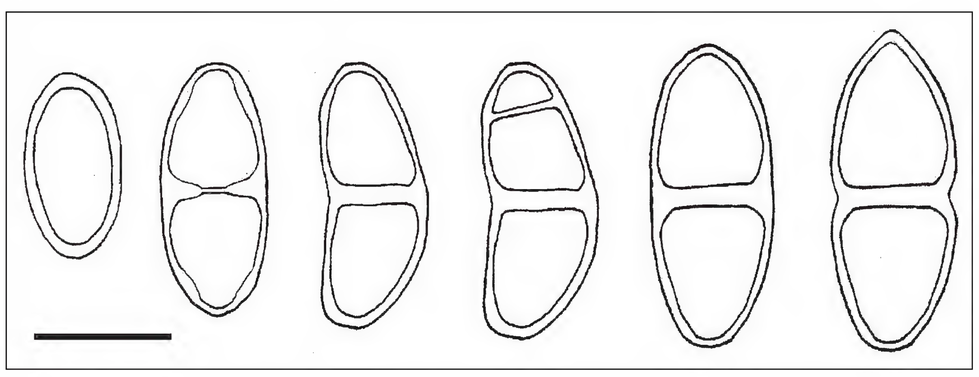

FIGURE 1 — Ascospore ontogeny in *Amandinea athrotaxiphila*. Scale = 10 µm.

Additional specimens examined

TASMANIA: type locality, 2024, *G Kantvilas 39/24* (HO); Turanna Heights, northwestern slopes, 41°45′S 146°22′E, 1270 m, 2024, *G Kantvilas 4/24* (HO).

Caloplaca ferruginea (Huds.) Th.Fr.

Nova Acta Regiae Soc. Sci. Upsal., ser. 3, 3: 223 (1861); — *Lichen ferrugineus* Huds., *Fl. Angl.*: 444 (1762); *Blastenia ferruginea* (Huds.) A.Massal., *Atti Reale Ist. Veneto Sci. Lett., ed Arti*, ser. 2, 3 (App. 3): 102 (1852).

Thallus effuse, very thin, mainly endophloeodal and best distinguished by a whitish discoloration of the bark substratum. Apothecia biatorine, sessile, basally constricted, 0.3–1.3 mm diam.; disc rusty orange, slightly pruinose, persistently plane; proper exciple ± concolorous with the disc, persistent throughout development, in section 50–60(–90) µm thick, hyaline within, at the outer edge with a granular, golden-orange layer that reacts K+ crimson and mostly dissolves. Hypothecium hyaline to pale yellow-brown, 60–70 µm thick, generally not inspersed, rarely with occasional oil droplets. Hymenium 90–100 µm thick, not inspersed, hyaline, in the upper part with a granular, golden-orange layer *c.* 10 µm thick as in the exciple; paraphyses simple to sparingly branched, divided mainly in the uppermost part, 2–3 µm thick, with the apices slightly expanded to 3–4 µm wide and often with occasional oil vacuoles to 4–5 µm wide; asci of the *Teloschistes*-type, 8-spored, 70–90 × 13–20 µm. Ascospores polaribilocular, hyaline, broadly ellipsoid, (10–)11–*13.2*–15 × (5.5–)6–*8.0*–10 µm (*n* = 70); septum prominent and occupying *c.* half of the spore length, 5–7(–8) µm thick. Conidiomata not seen. (pl. 5A)

Distribution and ecology

This species was first recorded for Tasmania by Crombie (1880), based on a collection made by Robert Brown in 1804 from the 'Derwent River'. The identification has never been confirmed, and the species was not recognised for Australia by Kondratyuk *et al.* (2012) but the name has persisted in various checklists up until the present day (McCarthy 2023). The recent Tasmanian collections cited here are from the twigs of *Athrotaxis cupressoides*, occurring as small clusters of apothecia within a rich assemblage of other lichens, including *Catinaria macrospora* Kantvilas, *Hypogymnia lugubris* (Pers.) Krog, *Menegazzia athrotaxidis* Kantvilas, *Ochrolechia xanthostoma*, *Pertusaria pertractata* Stirt., *Tasmidella subfuscescens* (Hellb.) Kantvilas, *Tephromela sorediata* Kalb, *Thelotrema lepadinum* (Ach.) Ach. and *Usnea* spp.

Discussion

Caloplaca is one of the largest genera of crustose lichens in Tasmania, and it is particularly prominent in coastal areas where it causes the bright orange, red or yellow coloration of littoral rocks. The genus is less species diverse or conspicuous in higher rainfall areas, although a small number of uncommon (and mostly still unidentified) taxa have been recorded. The taxonomy and identification of most species of the genus is generally acknowledged as difficult, and particularly so in Australasia where there is a pressing need to resolve the plethora of names based on Australian (including Tasmanian) types with the many Northern Hemisphere names that have also been applied. *Caloplaca ferruginea* is widely recorded in the Northern Hemisphere (e.g., Fletcher & Laundon 2009, McCune 2017). The name is applied here with some caution, although the Tasmanian material compares favourably to these published sources and displays the salient features of biatorine, rusty orange apothecia, a mostly non-inspersed hymenium and hypothecium, paraphyses with few (or no) oil vacuoles, and ascospores where the septum occupies almost half of the spore-length.

Contemporary classification of the large, heterogeneous 'form' genus *Caloplaca* based on DNA-sequence data (e.g. see Arup *et al.* 2013) places this taxon in the genus *Blastenia*, together with another alpine Tasmania taxon, *C. wilsonii* (= *Blastenia circumpolaris* Søchting *et al.*). However, this new approach has not been without controversy and has not been adopted in Australia (McCarthy 2023), where all species are retained in *Caloplaca*.

Specimens examined

TASMANIA: Lake Ball, 41°51′S 146°18′E, 1150 m, 2002, *G Kantvilas 108/02* (HO); George Howes Lake, southern end, 41°47′S 146°17′E, 1150 m, 2022, *G Kantvilas 57/22* (HO);

Mt Field National Park, Twisted Tarn, 42°40′S 146°34′E, 1120 m, 2024, *G Kantvilas 127/24* (HO).

Catinaria macrospora Kantvilas sp. nov.

Mycobank No. MB 855785

Similar to *C. atropurpurea* (Schaer.) Vězda & Poelt, but with larger apothecia, 0.5–1.3 mm diam., and larger ascospores, 15–28 × 6–10 µm.

Type: Australia, Tasmania, *c.* 2 km S of Turrana Bluff, 41°47′S 146°21′E, 1280 m, on *Athrotaxis cupressoides* in a small copse in alpine heathland, 16 February 2012, *G Kantvilas 35/12* (holotype—HO).

Thallus effuse, endophloeodal, barely discernible as a dull discoloration of the bark substratum; photobiont green, unicellular (*Dictyochloropsis*), with globose cells 6–12 µm wide. Apothecia biatorine, sessile, basally constricted, 0.5–1.3 mm diam.; disc dark reddish brown, epruinose, mostly persistently plane, becoming undulate to weakly convex at maturity; proper exciple ± concolorous with the disc or somewhat darker and a little glossy, persistent throughout development, in section 60–90 µm thick laterally, deep reddish brown, K± dull brown at the outer edge, becoming increasingly patchily and dilutely pigmented within, composed of radiating, conglutinated, branched and anastomosed hyphae with thread-like lumina. Hypothecium hyaline to pale yellow-brown, 40–50(–90) µm thick, inspersed with oil droplets to 6 µm diam. Hymenium 70–100 µm thick, not inspersed, hyaline, overlain by a reddish brown, K± dull brown epithecial layer *c.* 10 µm thick; paraphyses simple to sparingly branched, 1–1.5 µm thick, with apices reddish brown, to 3–4 µm wide; asci of the *Catillaria*-type, 8-spored, 70–80 × 16–20 µm. Ascospores 1-septate, very rarely with an additional septum towards one end of the spore, straight or slightly curved, frequently a little apiculate at the apices and slightly constricted at the septum, (15–)17.5–*21.2*–25(–28) × 6–*7.4*–8.5(–10) µm (*n* = 80); wall distinct, 0.5–1 µm thick; perispore often incomplete, *c.* 0.5–1 µm thick. Conidiomata not seen. (pl. 5B)

Chemistry: nil.

Etymology: The specific epithet alludes to the relatively large ascospores of the new species.

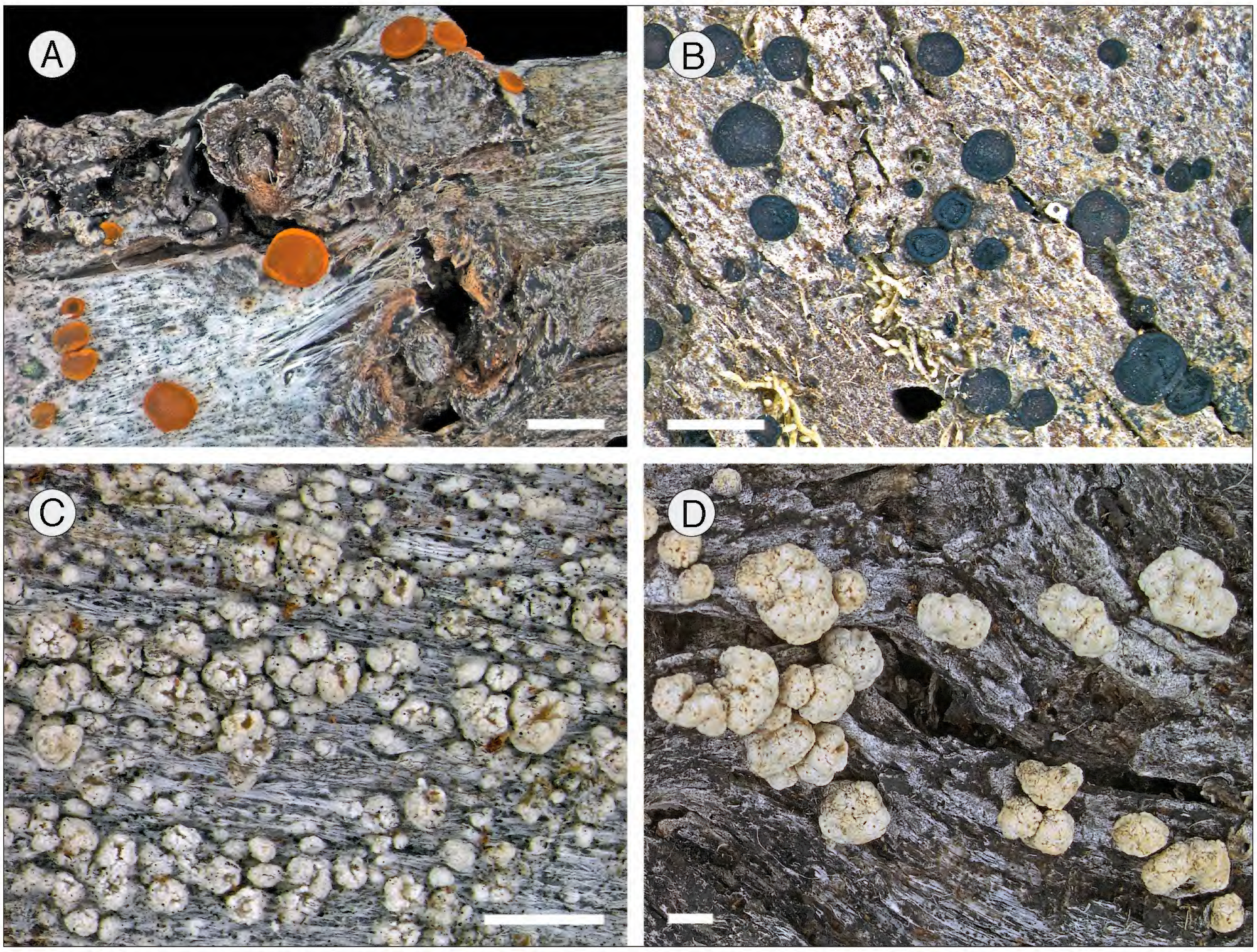

PLATE 5 — Species studied. **A** *Caloplaca ferruginea*; **B** *Catinaria macrospora*; **C** *Pertusaria comminuta*; **D** *Pertusaria tasmanica*. Scales = 1 mm. (Photos: J Jarman)

Ecology and distribution

Catinaria macrospora has been collected from the bark of old *Athrotaxis cupressoides* growing in small, isolated copses. There it grew on trunks seemingly devoid of other lichens, although occurring on one of the pieces of bark are the scattered, orange soralia of *Caloplaca wilsonii* S.Y.Kondr. & Kärnefelt. It has also been collected from the twigs of *A. cupressoides* fringing a lake shore, and there it is associated with a rather diverse epiphytic community that includes *Caloplaca ferruginea*, *Thelotrema lepadinum*, *Menegazzia athrotaxidis* and *Pertusaria flavoexpansa* Kantvilas & Elix.

Discussion

Catinaria is a small genus of about six species, found mostly in the Northern Hemisphere and the Americas. It is characterised by an ecorticate, crustose thallus containing a green, unicellular photobiont, biatorine apothecia, a cupulate proper exciple, *Catillaria*-type, 8–16-spored asci with a well-developed, uniformly amyloid tholus lacking any internal differentiation, simple to sparsely branched paraphyses with capitate, pigmented apices, and 1(–3)-septate, hyaline, ellipsoid ascospores with a thin, compact, gelatinous perispore. The recent classification of Jaklitsch *et al.* (2016) includes *Catinaria* in the Ramalinaceae, together with *Bacidia*, *Jarmania* and many other crustose genera. However, the distinctive ascus structure and halonate ascospores would appear to align it more readily to *Halecania*, which differs chiefly by having lecanorine apothecia, whereas the 1-septate ascospores and general appearance of the apothecia are similar to those of *Megalaria*, which differs by having *Bacidia*-, *Biatora*- or *Lecanora*-type asci and non-halonate ascospores. One species, the cosmopolitan *C. atropurpurea*, is widely distributed in temperate Australia and is locally abundant in Tasmania on the bark of mature shrubs and small trees in coastal scrub.

The new species is very distinctive and its larger apothecia and incrementally larger ascospores readily distinguish it from 'typical' *C. atropurpurea* as illustrated by numerous Australian and Tasmanian specimens studied, and as described in the literature (e.g., Hafellner & Ryan 2004, Gilbert 2009, Stenroos *et al.* 2016). When well-developed it also forms extensive, 'pure' patches up to *c.* 15 cm across. In contrast, *C. atropurpurea* has apothecia 0.2–0.8 mm diam. and ascospores 10–15 × 5–7 µm, and usually occurs as tiny thalli just a few centimetres across; furthermore, its ascospores have consistently rounded (rather than apiculate) apices, and the septum is frequently eccentric. However, despite these clear differences between the coastal *C. atropurpurea* with small ascospores and the alpine *C. macrospora* with large ascospores, two Tasmanian specimens remain undetermined. Both are from inland, wet forest habitats and have intermediate-sized ascospores, 13–20 × 5–8 µm; further collections may establish that these represent a further taxon in the genus.

Additional specimens examined

TASMANIA: Fisher Bluff, *c.* 700 m E of summit, 41°43′S 146°20′E, 1340 m, 2022, *G Kantvilas 393/22* (HO); George Howes Lake, southern end, 41°47′S 146°17′E, 1150 m, 2022, *G Kantvilas 58/22* (HO).

Other selected specimens examined

Undetermined taxon. TASMANIA: southern slope of South Sister, 41°32′S 148°10′E, 640 m, 20024, *G Kantvilas 377/04A* (HO); Florentine Bridge at 'Duke of Edinburgh' picnic area, 42°30′S 146°27′E, 360 m, 2005, *G Kantvilas 315/09* (HO).

Catinaria atropurpurea. TASMANIA: Flinders Island, Yellow Beaches, 40°13′S 148°15′E, 2 m, 1978, *JS Whinray 1231 p.p.* (HO); Cape Deslacs, 42°59′S 147°33′E, 1980, *G Kantvilas 231/80* (BM, HO); Little Musselroe River estuary, 40°46′S 148°03′E, 5 m, 2018, *G Kantvilas 181/18* (HO); St Helens Point, 41°17′S 148°21′E, 10 m, 2020, *G Kantvilas 99/20* (HO); Stony Head, 40°59′S 147°01′E, 50 m, 2020, *G Kantvilas 244/20* (HO, NY). SOUTH AUSTRALIA, KANGAROO ISLAND: Billy Goat Falls, 35°42′S 136°55′E, 200 m, *G Kantvilas 781/12* (HO); Grassdale Lagoon, 36°00′S 136°53′E, 20 m, 2015, *G Kantvilas 342/15* (HO). AUSTRIA: Mt Ebenberg, 47°19′N 12°47′E, 1200 m, 1990, *R. Türk* (*H Hertel: Lecideaceae Exsicc.* 261) (HO).

Pertusaria comminuta Kantvilas sp. nov.

Mycobank No. MB 885786

Type: Australia, Tasmania, Blue Peaks, southern slope overlooking Middle Lake, 41°44′S 146°23′E, 1240 m, on *Athrotaxis cupressoides* in a stand of open montane forest, 2 January 2023, *G Kantvilas 13/23* (holotype—HO).

Characterised by a thallus containing malonprotocetraric acid, irregularly deformed, verruciform apothecia, 4–8-spored asci, and ellipsoid ascospores, 52–85 × 29–44 µm.

Thallus crustose, effuse, cream-white, very thin, beset with coarse, irregular, highly fissured and sculptured, sessile or basally constricted, scattered or contiguous thalline granules and warts 0.2–0.8 mm wide containing the apothecia, sometimes fused together in irregular clumps to *c.* 1.5 mm wide; photobiont a unicellular green alga with globose cells 8–14(–18) µm diam. Apothecia mostly single per thalline wart; ostioles pale yellowish brown, *c.* 0.1 mm wide and a little sunken, with the margins irregular, ragged and dentate, becoming gaping, roundish, excavate and to 0.2 mm wide post-maturity. Proper exciple hyaline, 15–30 µm thick. Hymenium to *c.* 220–300 µm thick, hyaline, not inspersed, with the hymenial gel non-amyloid and the I+ blue reaction confined to the asci; paraphyses densely anastomosed, 1.5–2 µm thick, not capitate; asci 180–240 × 50–75(–80) µm (very few intact asci observed), (4–)8-spored, of the *Pertusaria*-type, with a weakly amyloid wall, a well-developed tholus with an intensely amyloid

cap, and a narrow ocular chamber when young. Ascospores biseriate or uniseriate in the ascus, simple, hyaline, ellipsoid, 52–*64.1*–78(–85) × (29–)30–*36.0*–43(–44) µm (*n* = 70); wall 5–8 µm thick, 2-layered, smooth on the inner surface. Pycnidia not seen. (pl. 5C, fig. 2D)

Chemistry: malonprotocetraric acid (major), protocetraric acid (± minor), fumarprotocetraric acid (± minor); thallus and apothecia K± gradually reddish brown, KC-, C-, P+ orange-red, UV-.

Etymology: The specific epithet means 'crumbling' in Latin and refers to the crumbly, rather abraded appearance of the thallus and apothecia.

Distribution and ecology

Most collections of this species are from the trunks of *Athrotaxis cupressoides* in alpine woodland, where it occurs on fibrous, otherwise seemingly bare bark largely devoid of other lichens. However, some are from the fibrous bark of *Eucalyptus delegatensis* subsp. *tasmaniensis* Boland in open heathy woodland, suggesting that with further fieldwork, it may prove to be more widespread.

Discussion

This is a generally rather nondescript and inconspicuous species and is therefore easily overlooked. The thallus is dominated by crumbly, sculptured verrucae, which commence development as scattered granules that usually fuse together to produce an uneven, irregular mass. Thus, unlike 'typical' *Pertusaria* species where the verrucae are ± roundish or hemispherical, with the ostioles visible as neatly rounded specks, depressions or holes, in *P. comminuta*, the apothecial verrucae resemble thallus granules, and the ostiole is a ragged opening where sometimes a pale yellowish-brown disc is partially visible. Post-mature verrucae can be excavate and appear as round, concave depressions.

Superficially, this species is similar to *P. tasmanica* (described below) when the latter is in a poor or juvenile state, insofar as both species have a creamy thallus, their asci are ± identical, and their ascospores are of similar size and shape. It was mainly the chemical difference that inspired further study, especially in the field where the morphological differences are stark: *P. tasmanica* with large, neatly globose apothecial verrucae, and *P. comminuta* with deformed, fissured and sculptured verrucae.

Additional specimens examined

TASMANIA: near Tom Thumb Plain, 42°53′S 147°11′E, 1965, *GC Bratt 2298 & JA Cashin* (HO); Hartz Mountains National Park, Lake Osborne Track, 43°13′S 146°45′E, 850 m, 1981, *G Kantvilas 492/81 & P James* (BM, HO); Dohertys Cradle Mountain Hotel grounds, 41°34′S 145°56′E, 830 m, 2003, *G Kantvilas 450/03* (HO); Mt Field National Park, track to Lake Nicholls, 42°40′S 146°39′E, 985 m, 2008, *G Kantvilas 350/08* (HO); Mt Field National Park, Twisted Tarn, 42°40′S 146°34′E, 1120 m, 2024, *G Kantvilas 124/24* (HO).

Pertusaria tasmanica Kantvilas sp. nov.

Mycobank No. MB 855787

Type: Australia, Tasmania, Traveller Range, *c.* 3.5 km NNW of The Gatepost, 41°56′S 146°06′E, 1230 m, on *Athrotaxis cupressoides* in open coniferous woodland, 12 March 2011, *G Kantvilas 146/11* (holotype—HO; isotype—E).

Characterised by a thallus containing norstictic acid, globose, verruciform apothecia, 0.8–2 mm diam., 6–8-spored asci, ellipsoid ascospores, 46–100 × 20–50 µm, and fusiform conidia, 10–15 × 1 µm, with a central bulge.

Thallus crustose, effuse, cream- to grey-white, very thin and discontinuous, dominated by verruciform apothecia; photobiont a unicellular green alga with globose cells 8–13 µm diam. Apothecia immersed in thalline verrucae with a usually wrinkled or cracked surface, globose, superficial, strongly basally constricted, cream-white, 0.8–2 mm diam., single or more commonly comprised of several apothecia fused together; ostioles 1–3 per simple verruca, to *c.* 10 in compound, fused verrucae, at first pale pinkish brown, *c.* 0.1 mm wide and a little sunken, gaping post-maturity. Thalline exciple 80–140 µm thick. Proper exciple hyaline, 20–30 µm thick. Hymenium to *c.* 400–450 µm thick, hyaline, inspersed with large oil droplets, 6–30 µm diam., with the hymenial gel non-amyloid and the I+ blue reaction confined to the asci; paraphyses densely anastomosed,

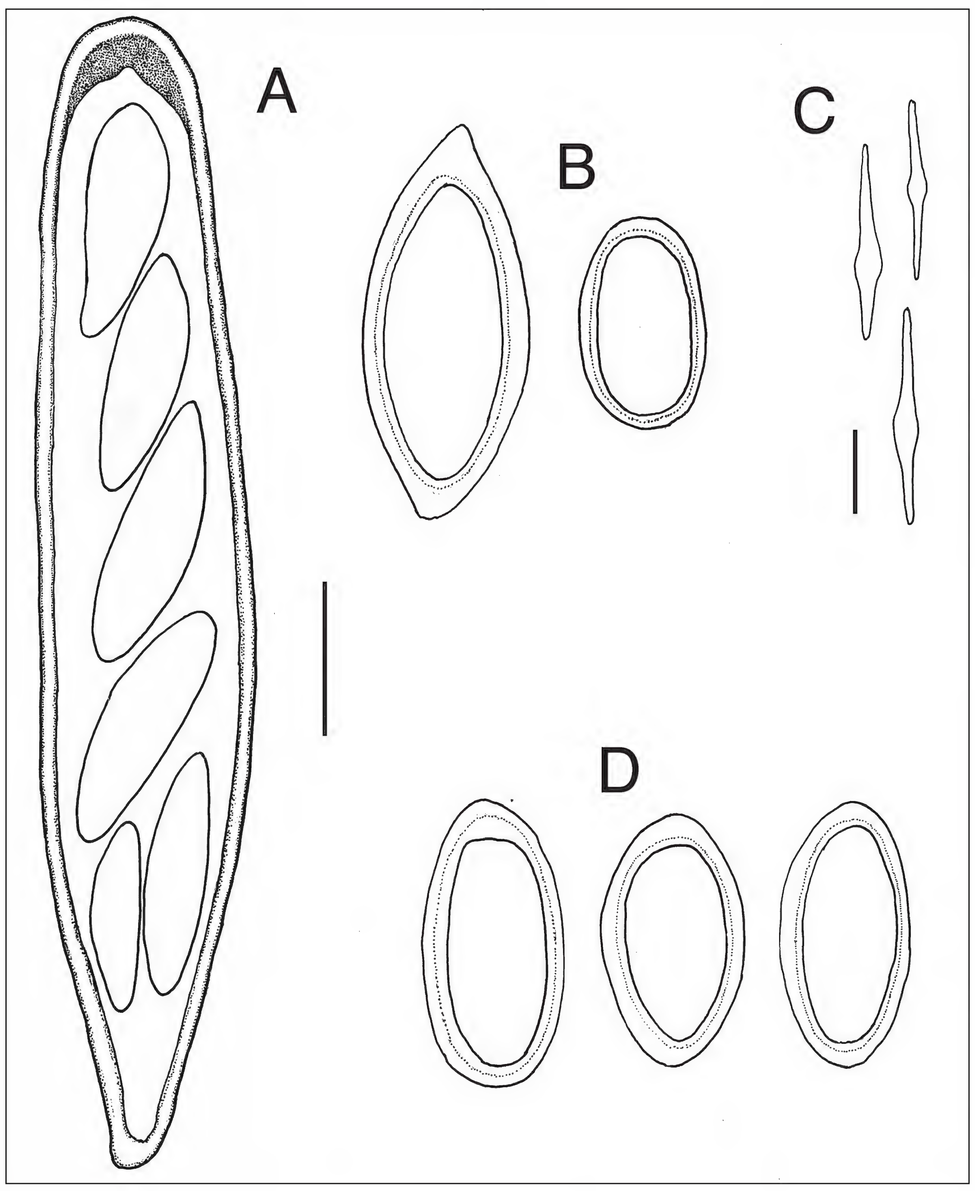

FIGURE 2 — Anatomy of *Pertusaria*. **A** The *Pertusaria*-type ascus, as seen in *P. tasmanica*, with amyloid parts stippled; **B** Ascospores of *P. tasmanica* (note the double wall); **C** Conidia of *P. tasmanica*; **D** Ascospores of *P. comminuta*. Scales: A, B, D = 40 µm; C = 5 µm.

1.5–2 µm thick, not capitate; asci 200–300 × 26–35(–50) µm (few intact asci observed), 6–8-spored but often with as many as 4 spores aborted by maturity, of the *Pertusaria*-type, with a weakly amyloid wall, a well-developed tholus with an intensely amyloid cap, and, when young, with a short, blunt ocular chamber. Ascospores uniseriate in the ascus, simple, hyaline, ellipsoid, (46–)50–*65.9*–80(–100) × (20–)22.5–*32.1*–44(–50) µm (*n* = 60); wall (2–)4–7 µm thick and inconspicuously 2-layered, swelling to 10 µm thick in K, smooth on the inner surface. Pycnidia immersed; conidia 10–15 × 1 µm, fusiform-acicular with a central bulge. (pl. 5D, figs 2A–C)

Chemistry: norstictic and connorstictic acids; thallus and thalline apothecial margin yielding red, needle-like crystals when sections are eluted with K.

Etymology: The specific epithet is based on the Tasmanian provenance of this taxon.

Distribution and ecology

Pertusaria tasmanica is an uncommon species that has been collected rather fortuitously in widely separated alpine localities. Whereas most collections are from the bark of *Athrotaxis cupressoides*, one is from *Diselma archeri* Hook.f. (cheshunt pine), a conifer that offers a bark of similar form and texture, and which frequently co-occurs with *Athrotaxis* in alpine woodlands and heathlands**.** As with the preceding species, *P. comminuta*, this new species occurs on fibrous bark essentially devoid of other lichens.

Discussion

The new species is very conspicuous due to its prominent, large, lumpy, thalline verrucae which contrast markedly with the dull grey-brown bark substratum, especially in cases where the thallus is rather poorly developed. However, also occurring in identical habitat is *Pertusaria comminuta*, which differs principally by its different chemical composition (protocetraric acid) and in having smaller, rather scurfy and abraded apothecial verrucae. Thus, care is required in identifying the new species and a simple chemical test with K is recommended.

Within the Tasmanian lichen flora, *P. tasmanica* is distinguished chiefly by the combination of its effuse to absent thallus, relatively large, globose apothecia, and large ascospores. The only other norstictic-acid containing species is *P. norstictica* A.W.Archer, which occurs in low rainfall, lowland areas and differs clearly by having a thick, continuous, pale olive-grey thallus, and hemispherical, apically flattened, mostly simple apothecial verrucae with black ostioles. The ascospore sizes of the two taxa are very similar. Also possibly related is *P. patagonica* Müll.Arg., described from Argentina and also recorded from New Zealand, but that species likewise differs by having a well-developed thallus as well as larger ascospores, 80–135 × 36–68 µm, with a rough inner wall (Messuti & Vobis 2002)

The current delimitation of genera within the Pertusariales (Cannon *et al.* 2021) has developed over many iterations and involved analysis of a range of characters that include the ascus, ascospores and thallus chemistry (e.g., Schmitz *et al.* 1994, Lumbsch *et al.* 1995) and, more recently, molecular data (e.g., Lumbsch & Schmitt 2002, Schmitt *et al.* 2006, Wei *et al.* 2017). Generic placement of the new species was, of necessity, based solely on a comparison of morphological and anatomical characters of herbarium specimens, chemical data and survey of the literature. Several genera were considered and compared during this study, with the classification of the new species determined by a combination of apothecial morphology, ascus type (fig. 2A) and the structure of the ascospore wall (fig. 2B). With this last character, it must be noted that the thick, gelatinous outer spore wall layer can become stripped away in preparing microscope mounts, and then the spores appear to be thin walled (GK pers. obs.). *Ochrolechia* was dismissed chiefly on account of it having an amyloid hymenium (as distinct from having the amyloid reaction confined to the asci), a particular ascus type where the outer wall is intensely amyloid and yields a 'fuzzy' appearance in light microscopy, ascospores with a thin, unlayered wall, and a thallus chemistry that comprises gyrophoric acid or its metabolic relatives, 5-*O*-methylhiasic acid or alectoronic acid. In the genus *Lepra*, the amyloid reaction is similar to that of the new species, in that it is confined to the asci, the asci themselves approximate the *Pertusaria*-type and there are species that contain depsidones such as norstictic acid, but it also has a particular apothecial form where the hymenium develops beneath a sorediate 'plug' and the ascospores have a single-layered wall; this genus too was dismissed. Also considered was the monotypic genus *Thamnochrolechia*, which has shortly stipitate apothecia, a non-amyloid hymenium, amyloid asci of the *Pertusaria*-type, and ascospores with a thin, single-layered wall. It is this last character that best distinguishes it from *Pertusaria sens. str.*, and hence this genus too was not considered.

Additional specimens examined

TASMANIA: Mt Field National Park, Clemes Tarn, 42°40′S 146°32′E, 1210 m, 2016, *G Kantvilas 6/16* (HO); plateau of Snowy South, 42°56′E 146°40′E, 1220 m, 2020, *G Kantvilas 39/20* (HO); Mt Field National Park, Twisted Tarn, 42°40′S 146°34′E, 1120 m, 2024, *G Kantvilas 123/24* (HO).

Xerotrema megalosporum Sherwood & Coppins

Notes Roy. Bot. Gard. Edinburgh 38: 368 (1980).

Thallus effuse and pale greyish to absent or endophloeodal, forming extensive, diffuse patches, doubtfully lichenised but with various, scattered algal cells often present. Apothecia perithecioid, 0.2–0.3 mm wide, black, initially immersed, soon erumpent and frequently overlain in part by vestigial, whitish thallus fragments; proper exciple ± carbonised, strongly incurved when young, typically radially split and ridged, with a central, ostiole-like opening, later gaping, bearing periphyses 15–20 µm long, 2 µm thick in the upper part, in section annular, 30–50 µm thick, brown or olive-brown with a greenish tinge at the outer edge, becoming more dilutely pigmented to hyaline within, I+

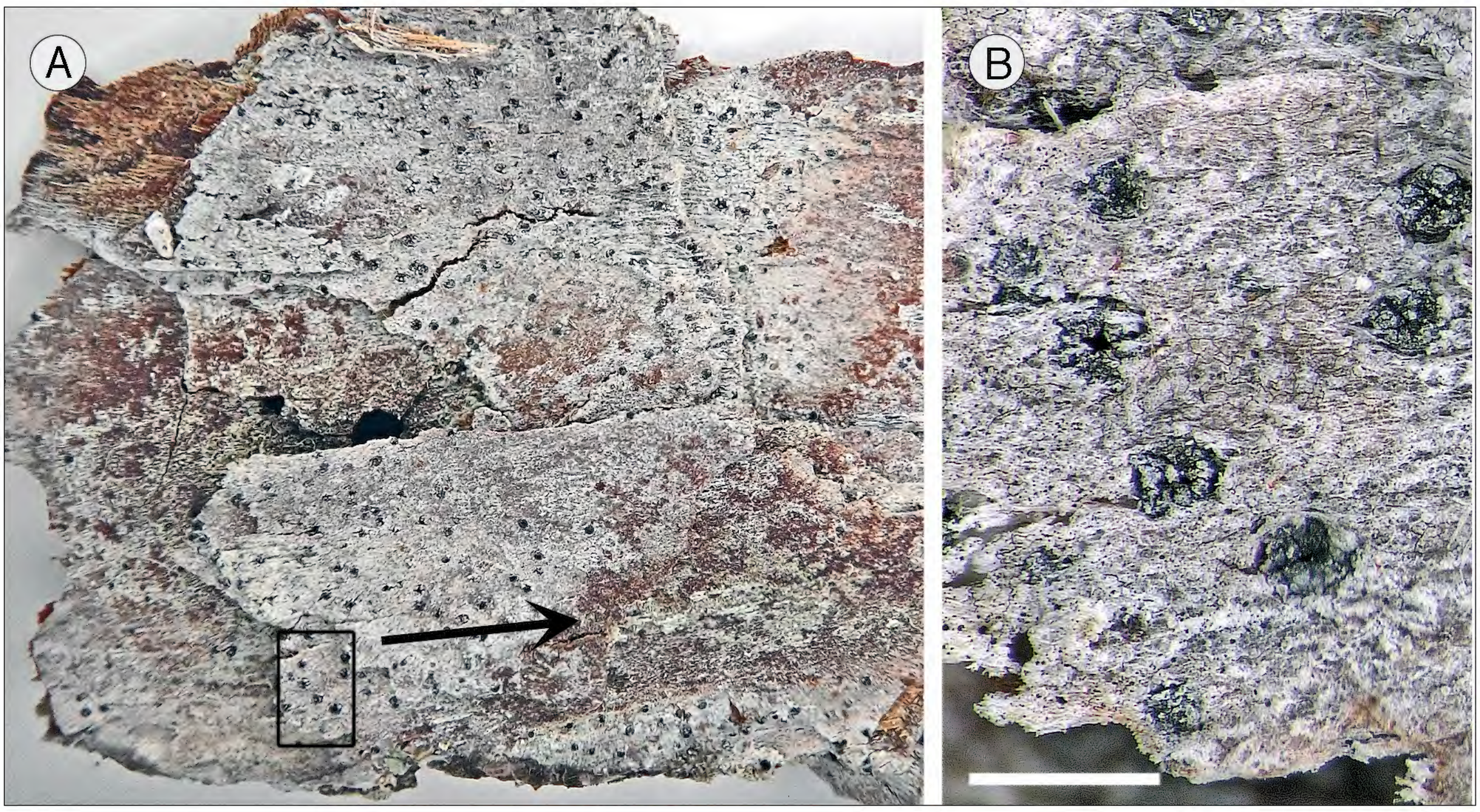

PLATE 6 — *Xerotrema megalosporum*. **A** Habit, showing black, speck-like apothecia; **B** Detail of apothecia. Scale = 500 µm. (Photos: J Jarman)

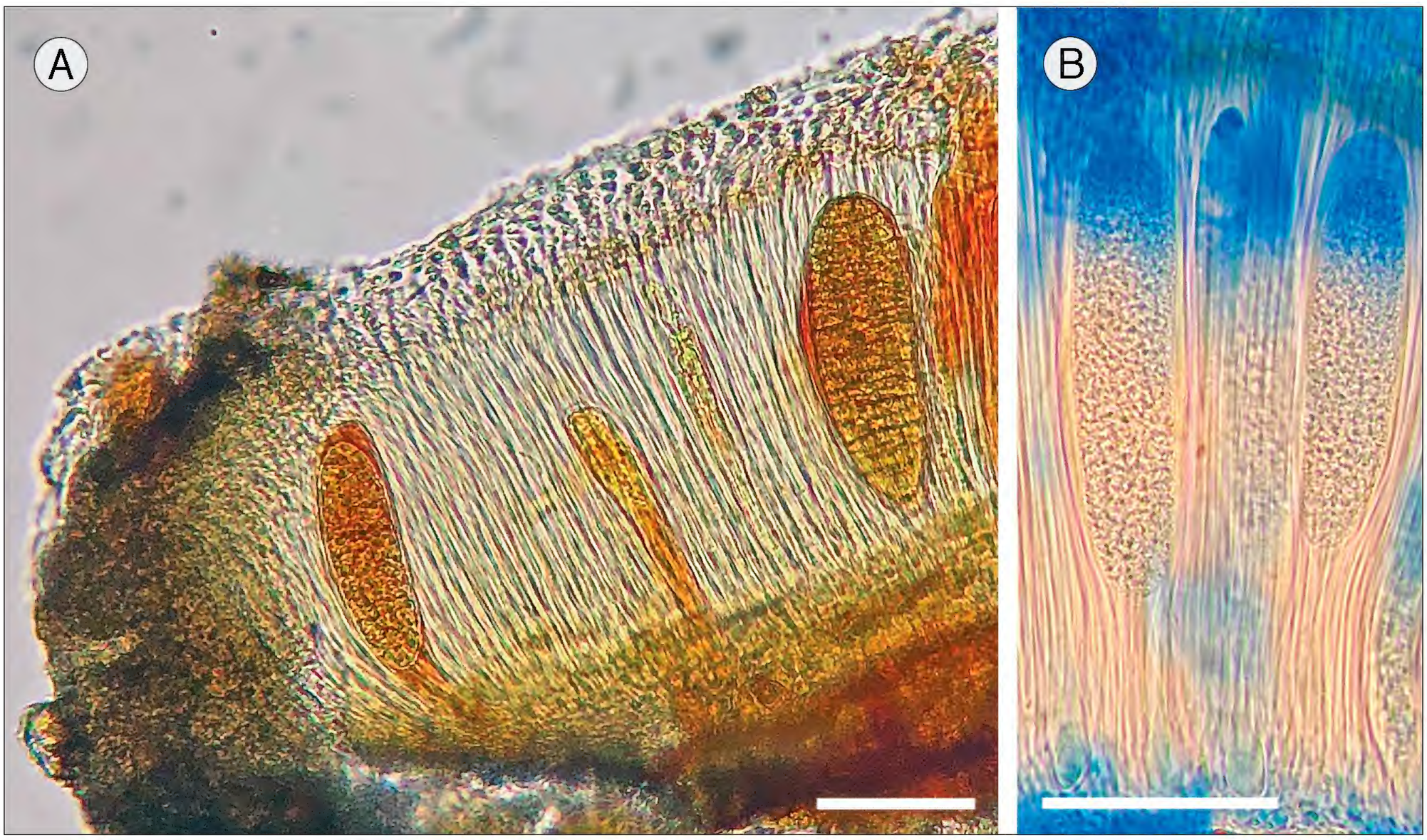

PLATE 7 — *Xerotrema megalosporum* anatomy. **A** Section through apothecium (in Iodine) showing asci with a single, muriform ascospore; **B** Portion of hymenium (in LCB) showing asci with contents disintegrated into conidia. Scales = 50 µm. (Photos: M Baker)

patchily mauve in the lowermost part (colour developing very slowly); disc plane to concave, generally obscured. Hypothecium hyaline, poorly differentiated, 10–20 µm thick. Hymenium hyaline, non-amyloid, 100–160 µm thick, overlain by a brown epithecial layer 5–8 µm thick; paraphyses slender, ± straight and parallel, mostly simple, or sparsely branched and anastomosed in the upper part, *c.* 1 µm thick, with apices not swollen; asci 130–150 × 20–40 µm, cylindrical to elongate-clavate, 1-spored, non-amyloid, with a ± uniformly thick wall when young but lacking a tholus. Ascospores highly muriform, (70–)*73–91.4*–124(–130) × (16–)18.5–*26.7*–35.5(–40) µm, hyaline, broadly ellipsoid to oblong, non-amyloid, thin-walled, non-halonate; locules *c.* 3–5 µm wide, irregularly rhomboid, sometimes breaking down into ellipsoid conidia 3–3.5 × 1 µm. (pls 6–7)

Distribution and ecology

This species is locally common at alpine elevations on the Central Plateau where it forms inconspicuous, extensive thalli, frequently many tens of centimetres in extent, on the old trunks of *Athrotaxis cupressoides* in small, isolated copses of open montane rainforest. It is also known from montane areas of Britain, Scandinavia and the Pacific northwest of North America, where it likewise grows on conifer wood.

Discussion

Xerotrema is a genus of two, highly inconspicuous crustose species, mostly occurring on wood in cool temperate areas of the Northern Hemisphere (Sherwood & Coppins 1980, Holien & Diederich 2010, Brodo 2020, Cannon *et al.* 2024). It is characterised by an ecorticate, inconspicuous thallus that is loosely associated with algal cells and doubtfully lichenised, perithecioid fruiting bodies (when young) that open by a roundish pore with an entire or dentate margin, an annular proper exciple, a non-amyloid hymenium, mostly simple or sparsely branched and anastomosed paraphyses, 1-spored, non-amyloid asci, and large, muriform ascospores. In some respects, it resembles some species of *Topeliopsis*, which differ by having a clearly lichenised thallus containing *Trentepohlia*, a cupulate proper exciple, and usually strongly amyloid ascospores. *Xerotrema megalosporum* is detected in the field by the abundant, speck-like, black, erumpent apothecia (pl. 6A). In some cases, the contents of the asci break down into conidia (pl. 7B), a feature seen in some other lichens with large, muriform ascospores, for example, *Gyalideopsis graminicola* Vězda & Kantvilas. The apothecia of Tasmanian specimens appear to be somewhat smaller than those of Northern Hemisphere populations, where 0.3–0.6 mm has been reported.

Additional specimens examined

Fisher Bluff, *c.* 700 m E of summit, 41°43′S 146°20′E, 1340 m, 2022, *G Kantvilas 395/22* (HO); Blue Peaks, southern slope overlooking Middle Lake, 41°44′S 146° 23′E, 1240 m, 2023, *G Kantvilas 8/23* (HO); *c.* 500 m N of Little Throne, 41°45′S 146° 23′E, 1230 m, 2023, *G Kantvilas 22/23* (HO); saddle *c.* 600 m E of Turrana Heights, 41°46′S 146°23′E, 1290 m, 2024, *G Kantvilas 27/24* (HO).

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REDISCOVERY AND SYSTEMATICS OF THE RARE BROWN-CAPED CARPET MOTH *CHRYSOLARENTIA EXCENTRATA* (GUENÉE, 1857 [1858]) COMB. NOV. (LEPIDOPTERA: GEOMETRIDAE: LARENTIINAE) IN TASMANIA

by Peter B McQuillan, Olga Schmidt, Catherine J Byrne and Margaret Warren

(with nine plates and one figure)

McQuillan, PB, Schmidt, O, Byrne, CJ & Warren, M (2024). Rediscovery and systematics of the rare brown-caped carpet moth *Chrysolarentia excentrata* (Guenée, 1857 [1858]) comb. nov. (Lepidoptera: Geometridae: Larentiinae) in Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 158: 79–86. ISSN 0080-4703. School of Geography, Planning, and Spatial Sciences, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia (PBM*). SNSB - Bavarian State Collection of Zoology, Munich, Germany (OS). Tasmanian Museum & Art Gallery, Hobart, Tasmania 7000, Australia (CJB, MW). *Author for correspondence. Email: p.b.mcquillan@utas.edu.au

We report the rediscovery of an attractive geometrid moth, the brown-caped carpet moth, not recorded in Tasmania for more than a century and presumed extinct. Originally described by the French lepidopterist Achille Guenée as *Coremia excentrata* from a specimen collected near Hobart in 1839 during the French expedition led by Dumont d'Urville, it was only observed on a few occasions before the last Tasmanian specimen was collected in the 1910s. A closer examination of its morphology reveals the holotype to be a male, not a female as claimed. We redescribe the species in detail and allocate it to the large Australian xanthorhoine genus *Chrysolarentia* Butler, hence *C. excentrata* (Guenée) comb. nov. Given its rarity, it is likely a candidate for active conservation management but gaps in knowledge include the discovery and description of its immature stages and food plants.

Key Words: *Chrysolarentia excentrata*, invertebrate fauna, rediscovered species, woodland fauna, looper moths.

INTRODUCTION

The geometrid moths of Tasmania are a conspicuous component of the macromoth fauna of the island, contributing about 312 species in total (McQuillan 2004). Among the rarest species are several presumed to have been more abundant in the past, based on museum records, but have apparently contracted in range to such an extent that individuals are now rarely encountered (e.g., McQuillan 2004, Threatened Species Section 2023). This paper reports the rediscovery of the attractive brown-caped carpet moth, a species not reliably reported in Tasmania for more than a century. McQuillan (1999) first drew attention to this moth as at risk of local extinction when preliminary surveys for a state census of the looper moth family Geometridae failed to uncover any recent records. It appears to be among the rarest species of Tasmania's extensive moth fauna. We also review the historical nomenclature of this poorly known species and redescribe it in detail to facilitate its recognition in future. Finally, we comment on the conservation status of this species in Tasmania and identify some gaps in knowledge that should be addressed.

METHODS

To form a better understanding of this species and its distribution, we have examined a cross-section of the available specimens in museum collections together with further evidence assembled from historical and contemporary images, formal publications and reputable online data aggregators such as iNaturalist (www.iNaturalist.org), the Global Biodiversity Information Facility (www.gbif.org/occurrence/search) and the Atlas of Living Australia (https://bie.ala.org.au/species/). Unfortunately, no mitochondrial molecular data for this moth was available on the Barcode of Life Data System (www.boldsystems.org/index.php).

We start by recounting the known circumstances of its discovery and review the species' complicated nomenclatural history. We then redescribe the species based on its phenotype and morphology. Dissections of the abdomen of both sexes have been made by the first two authors and the key features of the genitalia are described in detail.

Based on our review, we formally reassign "*Visiana*" *excentrata* to a more appropriate genus. Since the proposed taxonomic changes affect not only Tasmanian specimens, we also examined material from elsewhere in Australia in the taxonomic part of the study. Photomicrographs of the genitalia were obtained with a digital camera (ProgRes™ C10Plus, Jenoptic Laser Systems GmbH) and processed using Helicon Focus, version 5.1 (Helicon Soft Ltd). The digital images were enhanced and the plates compiled with Adobe Photoshop™.

ABBREVIATIONS USED

ANIC: Australian National Insect Collection, Canberra
MNHN: Muséum national d'histoire naturelle, Paris, France
NHML: Natural History Museum, London, United Kingdom
NMV: National Museum of Victoria, Melbourne, Victoria

PBMcQC: PB McQuillan collection, Hobart, Tasmania
QMB: Queensland Museum, Brisbane, Queensland
SAMA: South Australian Museum, Adelaide, South Australia
TDAC: Tasmanian Department of Agriculture Collection, New Town, Tasmania
TMAG: Tasmanian Museum and Art Gallery, Hobart, Tasmania
n.c.: no collector on label
n.d.: no date on label

RESULTS

Discovery, rediscovery and previous records from Tasmania

Coremia excentrata was first described by the Paris-based lepidopterist Achille Guenée in 1858 from a single specimen. It was collected by the Dumont D'Urville expedition to the Antarctic and south Pacific during the stay of the French corvettes *L'Astrolabe* and *Zélée* in the River Derwent between 13 December 1839 and 2 January 1840. The eastern shore of the Derwent is a likely collection locality for the type specimen as it is for various other Tasmanian Lepidoptera, including some butterflies (Couchman 1962). It was probably collected by Honoré Jacquinot, the surgeon and naturalist on board the *Zélée*, and younger brother of its commander, Charles-Hector Jacquinot. Élie Jean François Le Guillou, the surgeon-naturalist on *L'Astrolabe* also collected new moths near Hobart but these were described by him soon afterwards (Le Guillou 1841). The expedition returned to Toulon on 6 November 1840. Along with other natural history material, the specimens were absorbed into the collections of the MNHN later that year awaiting the attention of curators such as Guenée (Scoble & Pitkin 2024).

We found very few Tasmanian specimens available for study. There is a single individual (missing its abdomen) collected by WL May in the Tasmanian Department of Agriculture Collection. W Lewis May (1861–1925) was the eldest son of William May (1816–1903) a well-known orchardist at Sandford on the eastern shore of the Derwent River. Lewis was a talented amateur naturalist of broad interests but with a particular expertise in molluscs (Kershaw 1986). It is likely this specimen was collected in the Sandford area around 1910, coinciding with a short period when local naturalists showed heightened interest in the local Lepidoptera fauna. Arthur M Lea, the Government Entomologist at the time, visited farmers including orchardists as part of his duties and was known to encourage a deeper knowledge of local insects among his clients by submitting specimens to the Department of Agriculture for identification. Appointed to his role in 1899, Lea left Tasmania in 1911 to take up the position of Museum Entomologist in Adelaide where he remained for the rest of his career. The TDAC collection still preserves elements of Lea's material from this period and various Lepidoptera specimens bear the labels of Lea himself as well as local naturalists such as WK Findlay, JB Norman, GH Hardy and HHD Griffith.

After a long hiatus, attention was drawn to the rediscovery of this species via an image of a living moth posted to the popular citizen science app iNaturalist (www.inaturalist.org) by Margaret Warren at Opossum Bay, about 5 km SW of Sandford, in November 2022 (pl. 1). A second individual (pl. 2) was captured at the same location a few days later (https://www.inaturalist.org/observations/143755312) and is now preserved in the TMAG collection Registration no. F149393.

Taxonomic history and previous treatment

There has been considerable confusion in the literature regarding the correct name of this moth. Both the genus and appropriate species name have been unresolved historically. Guenée's original description in French was not accompanied by an illustration and was sufficiently vague for Edward Meyrick (Meyrick 1891, p. 831) to conclude that it may be a synonym of a broadly sympatric geometrid moth *Xanthorhoe strumosata* (Guenée), which bears a superficial similarity in size and wing pattern. Four years after Guenée, Francis Walker at the NHML described two geometrid moths, now synonyms of *excentrata*, and both involved specimens sourced from Tasmania. By the time of the first tranche of Turner's Lepidoptera of Tasmania checklist (Turner 1926), *excentrata* in various guises had been allocated to no fewer than three unsuitable European larentiine genera:

(1) *Coremia excentrata* in the original combination by Guenée 1857 [1858], p. 419, No. 1578.

(2) *Cidaria constipata* Walker, 1862. ("…also from Tasmania…") described from two syntypes (1♂, 1♀) preserved in NHML. Meyrick (1891, p. 834) later formalised the subjective synonymy of Walker's *constipata*.

(3) *Cidaria bifusata* Walker, 1862 holotype ♀ in NHML collected by the resident naturalist Morton Allport and probably sourced from Hobart.

(4) In his Tasmanian checklist, Turner (1926, p. 127) allocated *excentrata* to the European genus *Euphyia* Hübner, [1825]. This combination was adopted by Louis B Prout (1939, p. 287) in his wider study of the Indo-Australian Geometridae. He also named two infraspecific varieties or aberrations: *albiplaga* (Prout 1939) and *fuscifascia* (Prout 1939) based on minor differences in the phenotype of the fore wing. Based on similar instances among related species, these likely fall within the range of continuous variation in the species and, we argue, have little merit.

The holotype specimen of *excentrata* is extant in the MNHN, Paris, France, and a good-quality image is available online (pl. 3). It is incomplete, missing the left pair of wings and has been damaged in the past by a mould fungus, especially the head and antennae. The single frenulum spine visible on the underside image of the hind wing shows that, in fact, it is a male and not a female as claimed by Guenée [1858, p. 419].

For reasons outlined below, we now combine this species to the trans-Tasman genus *Chrysolarentia* Butler.

THE GENERIC POSITION OF *"VISIANA" EXCENTRATA*

A closer examination of "*Visiana" excentrata* shows that it must be excluded from *Visiana* Swinhoe as it does not share the combination of characters of that genus documented by Schmidt (2005, 2015). In particular, the male antennae are not bipectinate, the median band in the fore wings is usually lighter than the rest of the wing, and the fore- and hind wings beneath are marked with distinct, broad, dark brown postmedial bands. In the male genitalia, the ring between the seventh and eighth segments is modified; the tegumen is divided medially and without lateral tegminal arms; the costa of the valvae has an apical process protruding beyond the valval lobe at some distance from the apex, and the basal projecting arm of the costa is absent; a large calcar is also present. In females, the ventral surface of abdominal segment A7 is smooth; the apophyses posteriores are more than twice as long as the apophyses anteriores and the diverticulum of the corpus bursae is absent.

"*Visiana" excentrata* was used as an outgroup in her revision of the larentiine genus *Scotocyma* Turner by Schmidt (2005, 2007) who scored 50 morphological characters and their states for a phylogenetic analysis. She used this evidence to conclude that *excentrata* was misplaced in *Visiana*, first by Holloway (1997 and previously as pers. comm.) and adopted by McQuillan and Edwards (1996) but did not suggest an alternative placement.

This species is re-described more completely below and shows features consistent with the genus *Chrysolarentia* Butler (genotype *Chrysolarentia conifasciata* Butler, type locality: Melbourne, Victoria) to which we assign it formally. With the genotype it shares the following features: similar size and wing shape; hind wing colour in strong contrast to the fore wing; underside is yellowish with contrasting brown markings; venation with two areoles present in the fore wing; male antenna simple, segments prismatic and ciliate; abdomen not crested; male genitalia with uncus well developed, calcar long, bent in profile, setiferous on distal third, aedeagus very slender, caecum very short or lacking, one or more cornuti present; female genitalia with ovipositor of moderate length, apophyses posteriores about twice the length of the apophyses anteriores, antrum sclerotised and longer than wide (typically x 2), ductus bursae long and lacking a diverticulum, corpus bursae subglobose to globose and irregularly plicate.

SPECIES REDESCRIPTION

Chrysolarentia excentrata (Guenée) comb. n. (pls 1–8)

Coremia excentrata Guenée, 1857: 419. — Meyrick, 1891: 831 (incorrect synonymy of *Coremia strumosata* Guenée). Viette, 1950: 205.
Hydriomena excentrata — Turner, 1904: 256.
Euphyia excentrata — Turner, 1922: 260; 1926: 127.
Visiana excentrata — McQuillan & Edwards, 1996: 225. Holloway, 1997: 192. Scoble, 1999. Marriott 2011: 26, 27. Byrne, 2013.
"Visiana" excentrata — Schmidt 2005, 2015.
Cidaria constipata Walker, 1862: 1405. — Prout, 1939: 287; ab. *fuscifascia* Prout, 1939 (Gisborne) [var. a of Turner, 1904: 257]; ab. *albiplaga* Prout, 1939 (Gisborne) [var. b of Turner, 1904: 257].
Hydriomena constipata — Meyrick, 1891: 834.
Cidaria bifusata Walker, 1862: 1406. — Meyrick, 1891: 834 (synonymy of *constipata*). Prout, 1939: 287.

Type locality

Tasmania, near Hobart.

Material examined

Holotype ♂ (pl. 3), in poor condition and missing its left pair of wings and abdomen, labelled "TYPE [printed, red label]: *excentrata* [hand]: Museum Paris Tasmania Jacquinot 1841: 1270 41 [hand, round label]: *Coremia excentrata* Gn. X.419 [P Viette's hand]" image MNHN-EL-EL80826 in MNHN.

Other specimens examined (pl. 2)

Tasmania: 1♀, labelled "42.98449°S 147.41152°E TAS., Opossum Bay 10 m 4 DEC. 2022 M. Warren peri-urban herbfield Databased 121289 PBMcQ" (TMAG); 1♀, labelled "Sandford, n.d., W.L. May" (TDAC); 2♀, Tasmania, n.d., n.c. (QMB, possibly via the Wilfred B Barnard Collection); 1♂, labelled "Tasmania n.d., n.c." (SAMA, possibly via the Frank M Littler Collection); 1♂, Tasmania, n.d., n.c., genitalia slide GL5174 (PBMcQC). **New South Wales**: 1♂, labelled "NSW 25.ii.1947 LH Mosse-Robinson" genitalia slide GL5186 (PBMcQC). 1♂ 1♀, labelled "NSW n.d., n.c." genitalia slides Olga Schmidt.

Other images examined (pls 1, 4–7)

Tasmania: 1♀, Opossum Bay 10 m NOV. 2022 M Warren. **New South Wales**: 1♂, Devils Hole, Barrington Tops 7.xi.1991 JC Keast (-31.916 151.482 elev. 1,415 m) Database 31 043755 (ANIC); 1♀, Armidale 29.xi.1959 CW Frazier (-30.514 151.667 elev. 980 m) Database 31 043754 (ANIC); 1♀, Avalon 1.iii.1947 J Gemmell (-33.636 151.328 elev. 20 m) Database 31 043756 (ANIC). **Victoria**: 1♀, underside. VIC., Gisborne G Lyell (–37.493 144.589 elev. 450 m) (NMV).

Wingspan. ♂ 31–32 mm; ♀ 32–34 mm.

Head. Face rather smoothly scaled. Labial palpi rather thick, short, curved, at base covered with white scales, with terminal segment very small, rostriform. Antennae in both sexes simple, in male slightly swollen and ciliate.

Thorax. Smoothly scaled, brownish, with whitish scales ventrally. Fore tibia with an epiphysis closely appressed to tibia in both sexes. Hind tibia with two pairs of spurs.

Wings. Fore wing with costa slightly curved distally, apex acute, termen almost straight; ochreous fuscous in colour with a weak purple gloss, crossed by numerous wavy dark fuscous lines and a few variable white markings; a rather broad median band, often lighter than the rest of the wing (rarely darker), with a wavy, double medial outward prominence, its interior border not rounded. Fore wing

PLATE 1 — The first specimen of "*C.*" *excentrata* rediscovered in Tasmania by M Warren, 4 November 2022 at Opossum Bay (–42.984°, 147.411°, elev. 10 m): www.inaturalist.org/observations/143159010. Photographed in its alert stance with the hind wings partly exposed, after being disturbed while roosting high on a wall in a covered veranda. This specimen was not collected.

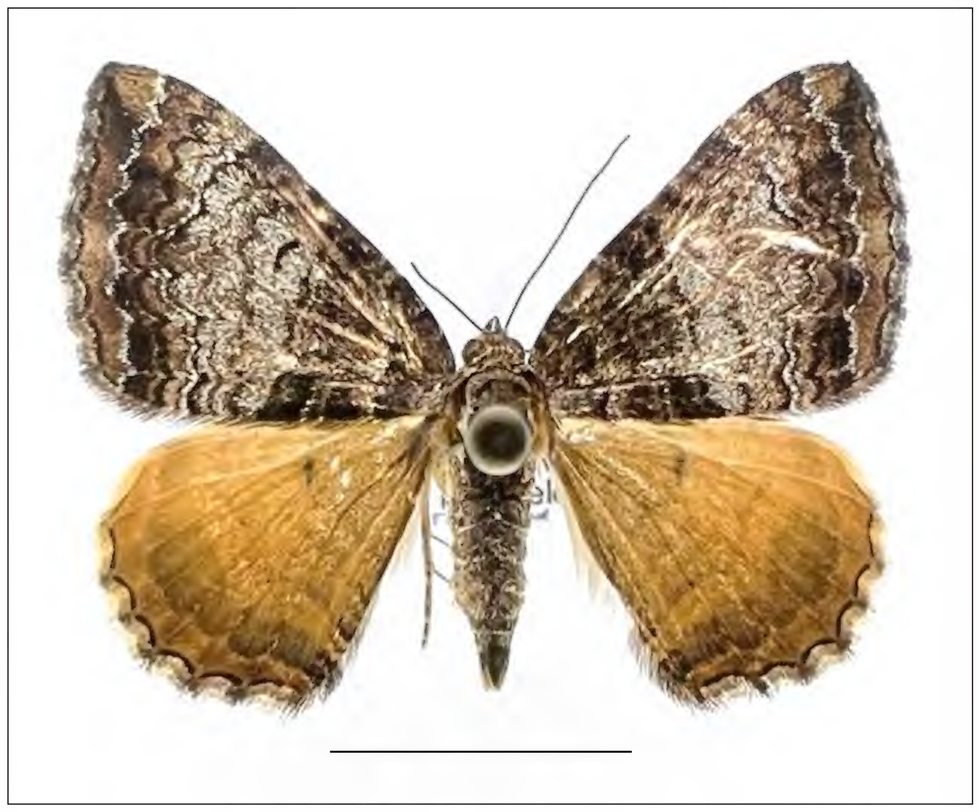

PLATE 2 — A second specimen of "*C.*" *excentrata*, a female, rediscovered by M Warren, 4 December 2022 at Opossum Bay (–42.984°, 147.411°, elev. 10 m) (TMAG). Scale line 10 mm.

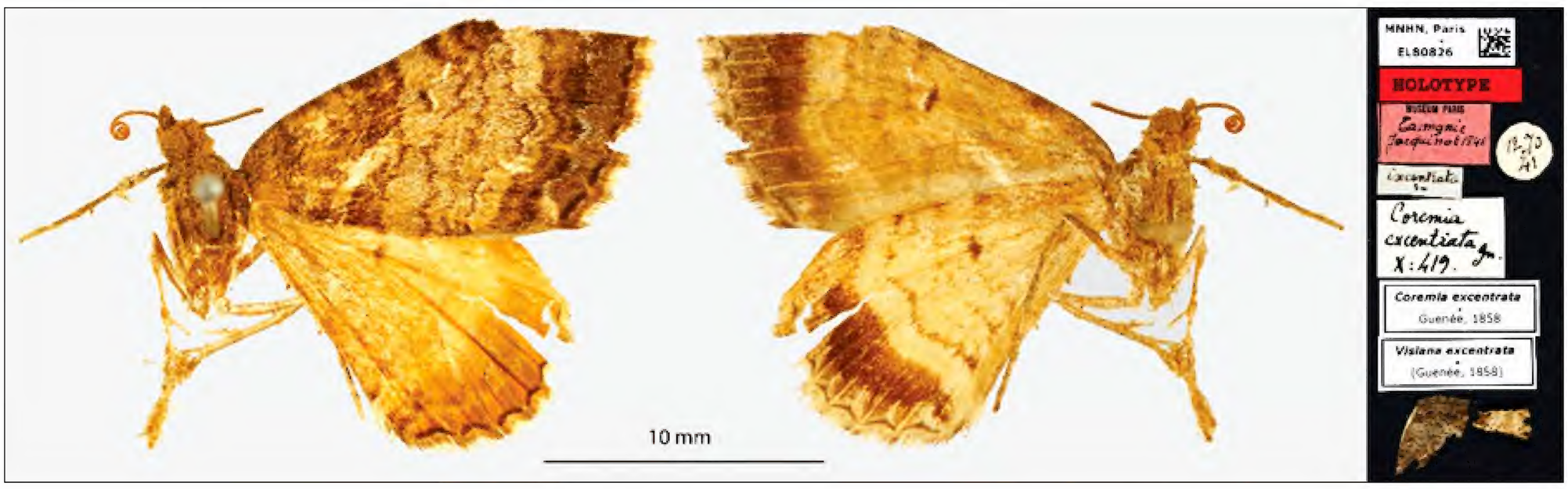

PLATE 3 — Holotype male of *Coremia excentrata* Guenée collected from Tasmania in 1839, preserved in Muséum national d'Histoire naturelle, Paris. Specimen MNHN-EL-EL80826 (credit: MNHN - V Durand 2023 CC BY 4.0) http://coldb.mnhn.fr/catalognumber/mnhn/el/el80826

PLATE 4 — ♂ *C. excentrata* NSW., Devils Hole, Barrington Tops 7.xi.1991 JC Keast (–31.916°, 151.482°, elev. 1415 m) ANIC Database 31 043755

PLATE 5 — ♀ *C. excentrata* NSW., Armidale 29.xi.1959 CW Frazier (–30.514°, 151.667°, elev. 980 m) ANIC Database 31 043754

PLATE 6 — "*C." excentrata* ♀ NSW., Avalon 1.iii.1947 J Gemmell (–33.636°, 151.328°, elev. 20 m) ANIC Database 31 043756

PLATE 7 — "*C." excentrata* ♀ underside. VIC., Gisborne G Lyell (–37.493°, 144.589°, elev. 450 m) NMV. (credit: P Marriott)

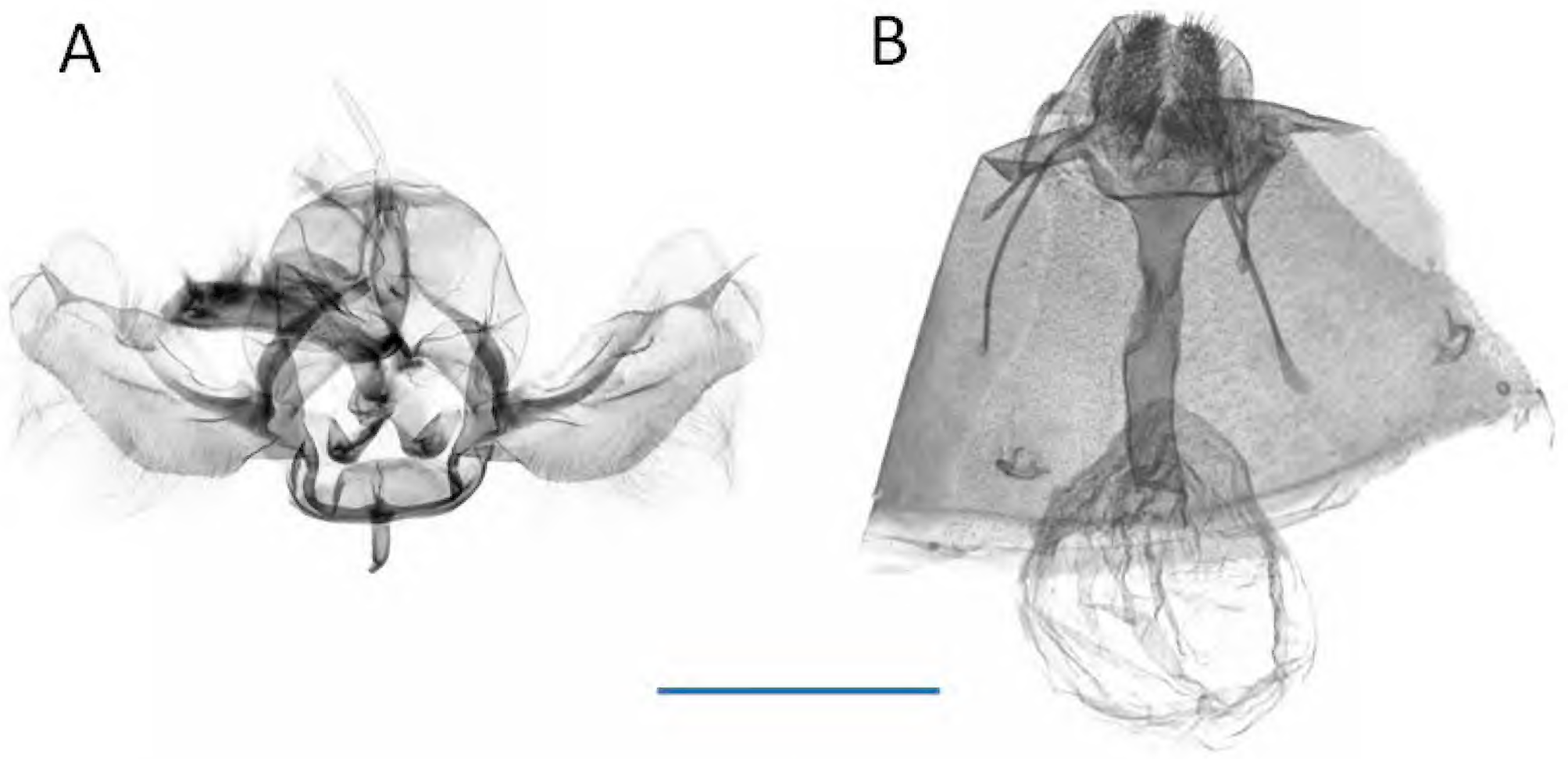

PLATE 8 — **A** ♂ genitalia of *Chrysolarentia excentrata* (from NSW); **B** ♀ genitalia. Scale line 1 mm. Both preps. by Olga Schmidt.

underside ochreous in its basal half, with a thin, wavy, brown medial line forming a medial outward projection, with a dark brown subterminal- and a greyish-brown terminal band, with a narrow discal dot. Hind wing with termen rounded and crenulated, usually brighter coloured than fore wings and of a reddish-ochreous hue which is paler towards the costa, with darker shaded postmedian band. Hind wing underside coloured and patterned similarly to the fore wings, but with medial line lacking a medial projection.

Abdomen. Coremata in males consist of eversible hair tufts in a very broad pocket laterally on each side of segment A7. A ring between segments A7 and A8 is modified, with lateral cavities. The last pair of abdominal spiracles are set ventrally on the coremata pockets. The ventral surface of abdominal segment A7 in females is smooth, compared to *Visiana* species. Tympanal ansa broad hammer-shaped, with medial rounded broadening, without a scoloparium.

Male genitalia (pl. 8A). Uncus slender, long, straight in profile, shifted ventrally. Tegumen inflated. Labides distally spatulate. Valvae elongated, with costa drawn to a distal free arm; valvula enlarged, bilobed, weakly differentiated from poorly sclerotised sacculus which is set with long marginal setae. Calcar large, distally exceeding lower margin of valva in profile, densely setiferous with long setae dorsally. Juxta with rounded basal lobes connected to the sacculi of the valvae. Vinculum rather narrow, with thin medial process (=saccus) reflexed. Aedeagus extremely slender, curved, no caecum; cornuti of a line of very slender short spines.

Female genitalia (pl. 8B). Ovipositor of moderate length; papillae anales rounded and densely setiferous. Apophyses posteriores are more than twice as long as apophyses anteriores. Lamella postvaginalis membranous; lamella antevaginalis a transverse sclerotised lip spanning the a. anteriores. Antrum relatively small, weakly sclerotised; ductus bursae relatively long and thin, weakly sclerotised,

PLATE 9 — View of Sandford district from Mt Mather (1948). (Tasmanian Archives, Jack Thwaites Collection NS3195/1/256)

corpus bursae small, subglobular, membranous-coriaceous, irregularly plicate longitudinally, without a diverticulum; ductus seminalis set ventrally, close to the ductus; signum absent.

Diagnosis

Within the diverse Tasmanian xanthorhoine fauna, the upperside of the hind wings is a distinctive colour, making the species relatively easy to recognise. Variously described as "brun-cannelle clair" [light cinnamon-brown] by Guenée 1857 [1858], as reddish ferruginous by Walker (1862) [in *bifusata* Walker, a synonym] and as ochreous-fulvous by Meyrick (1891, p. 835). It differs from *Chrysolarentia conifasciata* in the development of the male genitalia, especially the tegumen. The female differs in the vestiture of the papillae anales, and the somewhat coriaceous rather than thinly membranous corpus bursae which is plicate.

Habitat

Open eucalypt coastal woodland near sea level in Tasmania. Photographs from the vicinity of Sandford, taken around 1948, show open forest with an overstorey of *Eucalyptus viminalis* and *E. amygdalina* with scattered *Allocasuarina*, *Exocarpos* and *Acacia* sp. tall shrubs and with a grassy or sedgy ground layer in places (pl. 9). *C. excentrata* is less coastal and extends further inland on mainland Australia.

Distribution (fig. 1)

Eastern Australia south of the Queensland border, with a large disjunction to coastal southeastern Tasmania. On mainland Australia, it occurs sparingly in woodland localities from Killarney, Queensland (–28.334°,152.296°, 505 m elev.), and Armidale (–30.504°, 151.652°, 980 m elev.) and Ebor (–30.400°, 152.350°, 1350 m elev.) in New South Wales (Turner 1922), to southern Victoria in the vicinity of Gisborne (–37.485°, 144.591°, 440 m elev.) and Melbourne. Most northern populations seem to occupy woodlands at higher elevations, up to 1,415 m on the Barrington Tops.

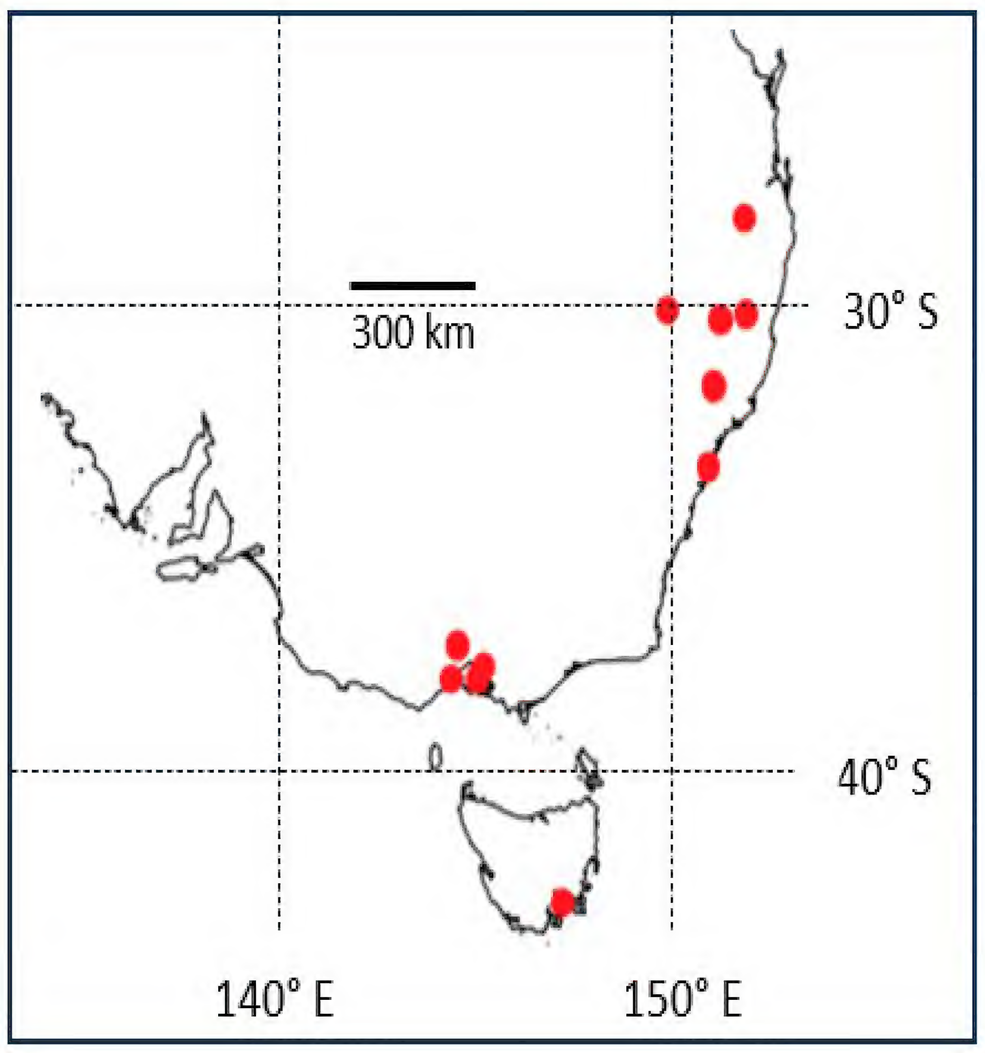

FIGURE 1 — The distribution of *Chrysolarentia excentrata* features large disjunctions.

Biology

Adult moths appear to be active in early morning light at or soon after dawn, then retreat to high vertical surfaces in shade later in the morning where they roost for the rest of the day. Similar behaviour has been observed in a sympatric relative, *Xanthorhoe anthracinata* (Guenée) (PBM pers. obs.) near Hobart. Attempts a few days later to attract specimens to ultraviolet lights at the original site and at a nearby coastal reserve, were unsuccessful. Mr Jim Duggan who runs a UV light source for documenting moths in nearby native woodland at Lauderdale, has not detected this species so far (pers. comm.). Although an iNaturalist image from Victoria shows a specimen settled on an illuminated sheet, it may be only weakly attracted to light sources. The flight period in Tasmania is late spring to early summer, but the span of collection dates in New South Wales suggests there may be an autumn generation as well. Immature stages and food plants remain unknown.

The contrast with the rather cryptic patterning of the fore wings suggests they may function as anti-predator startle or flash coloration, a feature well-developed in some other members of the genus which rest with the fore wings covering the hind wings (Meyrick 1891). The bright colours of this species are consistent with some related day-flying geometrids but there is no evidence so far that *C. excentrata* is diurnally active. A rare species in Tasmania, it has not been collected for more than 110 years; there are also few recent records from mainland Australia. The widespread decline of native temperate grassy woodlands on fertile soils is possibly implicated.

DISCUSSION

We confirm that *C. excentrata* is a conventional member of the largely amphipolar larentiine tribe Xanthorhoini which includes four genera in Tasmania (McQuillan 2004). The presence of a calcar in the male genitalia is diagnostic for this group (Pierce 1914, Schmidt 2013) and this feature is clearly visible in dissections of this species. Although *C. excentrata* does not seem to share a few presumably chrysolarentiine characters, like the shape of the tegumen, uncus and saccus, in all major aspects, including its general phenotype, it is consistent with the Australian genus *Chrysolarentia* Butler, the largest local genus of xanthorhoines present in southern Australia. Molecular approaches could provide additional evidence.

In a brief overview of Tasmanian Geometridae, McQuillan (2004) reported no recent distribution records for this species (listed as '*Coremia' excentrata*) for Tasmania but inferred its likely association with dry forest from occurrence records on mainland Australia. Since that time, more than 200 moth sampling events in Tasmania by three of the authors have failed to detect *C. excentrata*, emphasising its rare and restricted status in the state.

It is possible, but unlikely, that *C. excentrata* is an occasional migrant to Tasmania across Bass Strait since various other macromoths, including geometrids, can disperse across this 200+ km-wide seaway (e.g. Hill 2013). Occurrence records from the north coast of Tasmania would be expected in such a scenario. A government entomologist, Mr Lionel Hill, maintained a Rothamstead-style mercury vapour light trap near Devonport for almost 30 years until 2019 without detecting this moth.

Although some species of *Chrysolarentia* are widespread in Tasmania, others are more restricted in their distribution including a suite of alpine and subalpine taxa. A related geometrid, the grassland or Tunbridge looper *Chrysolarentia decisaria* (Walker) is a listed threatened species (Threatened Species Section 2023). A diurnal moth active in autumn, the Tunbridge looper is now restricted to scattered patches of native or semi-natural grassland in the dry Midlands. There are parallels with several xanthorhoine moths in New Zealand which have become increasingly rare due to intensification in land use, especially livestock grazing (Patrick 2000).

Conservation needs

Although woodland and heathy habitats are widely established on sandy soils close to sea level in southeastern Tasmania (The LIST 2023), much coastal woodland near Hobart is now cleared for farming or housing. It is noteworthy that the population reported here is likely to be living close to the original type locality for this moderately wide-ranging species (30°S to 42°S). Interestingly, the occurrence of *C. excentrata* in a semi-rural habitat suggests a degree of tolerance for modified environments and some optimism for its persistence.

The future discovery and documentation of the immature stages will greatly aid conservation efforts as supplementation of populations by release of reared individuals has been successful for rare moths elsewhere (Baker *et al.* 2016, Butterfly Conservation 2019). Larvae of most members of the Xanthorhoini are sluggish, generally nocturnal caterpillars which mostly feed on native herbs although a few species can accept exotic food plants, e.g., *Epyaxa subidaria* (Guenée) (McFarland 1988, Schmidt 2016). Captive rearing experience with some other Tasmanian xanthorhoines indicates that pennyworts *Hydrocotyle* spp., some native buttercups *Ranunculus* spp. and *Geranium potentilloides* are widely accepted in their diet (PBM, pers. obs.).

The following conservation measures and future research strategies are recommended: (i) further surveys be undertaken in the flight season (late spring–early summer) to clarify the Tasmanian distribution and status of *C. excentrata*; (ii) eggs for rearing be obtained from females so that the immature stages can be recognised, especially the larvae, to facilitate surveying; and (iii) *C. excentrata* should be formally assessed for listing as a threatened species under Tasmania's *Threatened Species Protection Act* 1995.

ACKNOWLEDGEMENTS

We are grateful to Drs John Ireson and Melissa Houghton for arranging access to the TDAC collection in Hobart.

The late Mr Ted Edwards assisted us at the ANIC in Canberra. Mr Peter Marriott organised images of Victorian specimens and Mr Jim Duggan from Lauderdale discussed his trapping results with us. OS thanks Dr Stefan Schmidt (SNSB-ZSM) for support. Plates 4, 5 and 6 are used under a Creative Commons Licence – Attribution (2011) CSIRO and Centre for Biodiversity Genomics. We thank Alicia Marchant, Archivist at Libraries Tasmania, for approval to reproduce Plate 9.

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(accepted 13 September 2024)

FIFTY YEARS OF THE ABORIGINAL MOVEMENT IN LUTRUWITA/TASMANIA AND SOME REFLECTIONS ON THE NEXT FIFTY YEARS

by Heather Sculthorpe

Sculthorpe, H (2024). Fifty years of the Aboriginal movement in Lutruwita/Tasmania and some reflections on the next fifty years**.** Summary of a lecture presented to the Royal Society of Tasmania, 4 August 2024. *Papers and Proceedings of the Royal Society of Tasmania* 158: 87–91. ISSN: 0080-4703. Author contact: Heather.S@tacinc.com.au

PREFACE

This paper is from a lecture presented by Heather Sculthorpe to the Royal Society of Tasmania on 4 August 2024. The address was delivered on Aboriginal land at Piyura Kitina/ Risdon Cove and attended by a large audience of RST members and the public. This paper has been published with the author's permission.

ABOUT THE AUTHOR

Heather Sculthorpe has dedicated her life to advocating for the rights and well-being of Tasmania's Aboriginal community and her name is synonymous with strength, resilience, and unwavering commitment to justice. Heather has been a formidable advocate for the recognition and respect of Aboriginal rights, tirelessly working to ensure that the voices of her people are heard and valued. Throughout her career, Heather has played a pivotal role in various initiatives aimed at addressing the injustices faced by Aboriginal communities. Her work spans across education, health, and social justice, impacting countless lives and inspiring many to join the cause.

In 1982 Heather Sculthorpe became the first Tasmanian Aboriginal to obtain a Law Degree from the University of Tasmania. She also has an Honours Degree in Law, an Arts Degree, a Graduate Diploma of Environmental Management and is a graduate of the Australian Institute of Company Directors. Heather established a career in the administration of Tasmanian Aboriginal organisations and in 2016 was appointed Chief Executive Officer of the Tasmanian Aboriginal Centre, a position she still holds at the time of this lecture. In 2016, in recognition of her outstanding achievements, Heather was listed on The Australian Women's Register.

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ACKNOWLEDGMENT

Remember with me please the Palawa men, women and children who lived their lives on these lands before the English invasion. Remember the Mumirimina who spent time at Kangaroo Bay, down river in this same landscape, on the outskirts of the emerging town after they were pushed off their land in this very spot and some of whom were later executed in the town goal in Macquarie Street, Hobart.

EARLY WORK OF AIS AND THE TAC

The Tasmanian Aboriginal Centre is an Aboriginal community organisation developed in the early 1970s and funded by the federal government since 1973. It was incorporated as the Aboriginal Information Service (AIS) in November 1973 and changed its name to Tasmanian Aboriginal Centre (TAC) in August 1977. Health and housing were the big needs of the Aboriginal community in the early days of our organisation's existence. Infectious diseases, especially among children, were a significant focus of our work. We weren't funded for that of course. The Social Welfare Department knew best and they decided a 'homemaker service' was most needed for the families removed from Cape Barren Island and relocated into substandard housing in Launceston, Burnie and Hobart. Much of our early work was voluntary and it wasn't until 1973 that we obtained Commonwealth funding for a legal service.

The TAC has become a major provider of services to the Aboriginal community as well as being at the forefront of the political movement for Aboriginal rights. The Centre is now a registered charitable organisation, a registered Training Organisation (the only Aboriginal RTO in the State), a major employer of Aboriginal people with over 200 staff, about three quarters of whom are Aboriginal, and the leader in Aboriginal language and repatriation efforts. The TAC has premises in six locations around the State with workers outposted to the Furneaux islands. Our

programs are far ranging spanning across social, economic and environmental issues and include:

- General Practice clinics and Aboriginal Health Worker programs around the State,
- A counselling service,
- On country well-being programs,
- Parenting programs,
- Youth service,
- Early childhood development and an Aboriginal Children's Centre,
- Illness prevention and health education programs,
- Family support program,
- Liaison with child safety services on the wellbeing of children to keep them out of State care,
- Supporting Aboriginal children in care,
- An Aboriginal language retrieval and community education program,
- Management of returned Aboriginal lands in six locations under the Indigenous Protected Areas and Working on Country programs,
- The development of a Sea Country program centred around the Furneaux islands,
- Repatriation of ancestral remains and cultural objects,
- A native food catering and awareness program,
- Aboriginal tourism projects,
- A junior ranger program designed to engage school students in Aboriginal cultural and land matters recently funded in only three locations,
- An Aboriginal skills and employment program just getting underway,
- A suicide prevention program,
- Hearing health and good use of medicine projects,
- Development of a family violence awareness and prevention program,
- Substance abuse prevention and recovery programs,
- Vaccination and screening programs,
- Hepatitis C awareness and treatment,
- Foetal Alcohol Spectrum Disorder awareness project in development,
- Advocacy and referral services.

The TAC is also the Tasmanian representative body on the National Aboriginal Community Controlled Health Organisation (NACCHO), on the national body for the protection of Aboriginal children (SNAICC Board) and the Coalition of Peak organisations for *Closing the Gap*.

While there has been significant growth in the services provided, some important programs have been lost. We no longer have an Aboriginal school that we once operated at Piyura Kitina /Risdon Cove or the significant Aboriginal Legal Service that we operated for 40 years. This legal service was lost when Senator George Brandis re-allocated the funds to Victoria and the State Attorney General Archer later gave funds to a conglomerate more amenable to the Tasmanian government. However, our endurance and lasting success are due firstly to the support of the Aboriginal community, to the priority we have always given to financial probity which has allowed us to withstand political attacks, and, in no small measure, to the support we receive from the wider Tasmanian community.

It is sometimes alleged that we care more for money than anything else and that we've become too big. I consider our Aboriginal services to be the equivalent to the Aboriginal community as the public service is to the general community – apart from tertiary services like hospitals – so it's impossible for us to be too big especially when our needs remain so high. I certainly consider the TAC to be different from the recent spate of organisations which managed to secure registration with the Commonwealth Office of the Registrar of Indigenous Corporations ORIC with the consequence that they are now ensconced as Indigenous Corporations even though some have few Aboriginal members or directors. For example, in June 2023, the Land and Sea Aboriginal Corporation Tasmania had 6 Directors and 10 members (https://register.oric.gov.au/document.aspx?concernID=4555544) yet this is the organisation that the Tasmanian government gave an abalone quota said to be for the Tasmanian Aboriginal community but refuses to supply our native food business with nitipa/abalone.

I'm emphasizing that there is a huge gulf between organisations registered as Indigenous and those responsible to a large community of Aboriginal people and governed by Aboriginal people.

NON-INDIGENOUS SUPPORTERS

A theme that runs through the history of the TAC, and especially in the early days, was the support of non-indigenous people, including white professionals. Reverend Jim Colville for example was an early supporter of the Aboriginal community by helping those in need, well before his *Colony 47* organisation became corporate. Dr David Evans from the Commonwealth Health Laboratories in Battery Point helped Aboriginal people with medical advice although this arrangement existed only in Hobart and was limited in extent. And then of course there were lawyers like Professor Derek Roebuck and Pierre Slicer, later Judge Slicer, both of whom had communist affiliations and were strong defenders of political freedom. The Communist Party of Australia was quite influential throughout Aboriginal Australia in the 1970s with activists like Charles 'Chicka' Dixon prominent amongst them and Frank Hardy in the forefront of the fight for Aboriginal land rights. While we had a few supporters in State Parliament at the time, most politicians were still wondering what the fuss was about as they had learnt in school that Truganini was the last Tasmanian Aborigine.

There were quite a few outside the Aboriginal community and a few within who considered we were being indoctrinated by our Communist supporters. What we learnt about the Communists was that we had to put our community first and exercise our judgment about who could be trusted and who could not.

LACK OF POLITICAL TRUST AND WILL

We've learnt many lessons over the years about politics, the deception and how often games are played. For example, the Labor Party appointed the brother of one of their Ministers in the 1980s to undertake a study of Aboriginal needs. We did our best to contribute but ultimately turned our back on the process. Things haven't changed much for over 40 years later when the government agreed to examine proposals for truth telling and treaty; they then appointed two white people to undertake the task. As far as I know, that has not happened in any other jurisdiction in Australia where governments have agreed to examine the idea of Treaty. In this State we're still trying to hold governments to account on their undertaking to commit to the process whereas most other States have made considerable progress, some nearing the end of their journey.

Unfortunately, there is now a goodly number of Aboriginal people who also play those dirty games like those who accused us of selling out by undermining the thesis of Pascoe's book by exposing his fraudulent claim to be Palawa or by pointing out the irrational claims of some pro-*Voice* proponents with emotional pleas about how the lives of young Aborigines in custody would be ruined without a *Voice* in the Australian Constitution.

Coincidentally or not, many of those same people were in the forefront of the *Voice* Referendum proposal and had similar pejorative terms for those like us who were sceptical of the claims made for the *Voice*. After the *Voice* referendum was defeated in October 2023, we are now witnessing Prime Minister Albanese making the same mistake all over again with his announcement in August 2024 of a new way forward for Aborigines as part of the national economy by returns from renewable energy. While this announcement attracted immediate support from Aboriginal academics who had been prominent in the *Voice* campaign, there was clearly no evidence that consultation with the wider Aboriginal community had taken place. There was certainly no consultation with Tasmanian Aborigines of course, or at least not with those whose first loyalties remain with our own community.

We consider ourselves environmental guardians highly conscious of climate change, species extinction, deforestation and we see every day the destruction to our cultural heritage from the rush to renewables like winds farms at Pilitika/ Robbins Island and St Peter's Plains. So, while our new program grants these days often require a co-design phase of thorough consultation, there is no similar process undertaken by governments. This is not only hypocrisy but ignores the principles of *Closing the Gap* to which all governments still pay lip service.

ABORIGINALITY AND THE EXTINCTION MYTH

When our organisation first started, we had two major tasks. The first was to engage with the Aboriginal community throughout the State. That role continues to this day. The second was to combat the extinction myth. I'll give only one example of the latter. In a pamphlet from the Tasmanian Government Printer dated 1900, the missionary James Backhouse Walker wrote,

> *During the early years of the Colony, when the blacks were, on the whole, friendly, no one thought it worthwhile to take the trouble of studying their ways, or of making any attempt to investigate their tribal customs… But the scientific study of anthropology had not then begun, and the blacks were so low in the scale of civilization that they were deemed unworthy of attention. For no one then recognised that it was the very fact of their being at the bottom of the scale that would have made a thorough knowledge of their ideas of such interest and importance.*

Despite their attempts at justification, that's the same mantra as archaeologist Rhys Jones and film maker Tom Haydon portrayed in their 1978 film *The Last Tasmanian.* While many still assert that film did us a favour by bringing the horrors of grave robbing of our ancestors to public attention, its legacy was also embedding the myth of our extinction, the effects of which we are still feeling today. I will add that so concerned was Rhys Jones for our culture that he failed to return the results of digging up our heritage and it was all destroyed in the Canberra bush fires a couple of decades ago.

As our visibility and influence increased, so did the myths, misunderstandings and lies generated about us. Without any consultation, so many well-known white novelists have felt entitled to add their opinion about who best represents the Tasmanian Aboriginal community and the disgruntled groups who disagree with the TAC. Whether this was due to politics or simply tall-poppy syndrome, I do not know - but some of it was plain vicious and the consequences of divisive narratives remains so today.

Here's just one example that still rankles to this day. In the Australian Guardian and UK Guardian of October 2002 in an article headed *The Lost Tribe* the Tasmanian novelist Richard Flanagan wrote:

> *Over the past 30 years the Tasmanian Aboriginal community has been resurgent, finding an organised voice in the Tasmanian Aboriginal Centre (Tac). But over time the radicals of the 1970s transformed into a black political establishment. Tac's sense of identifying only those allied to its politics as the Aboriginal community, and those opposed to Tac and its politics as not being Aborigine, led to a growing anger on the part of those Aborigines who didn't see eye to eye with Tac.*
> https://www.theguardian.com/world/2002/oct/14/australia.features11?CMP=share_btn_url

These accusations are so demonstrably untrue that one wonders what motivates a white novelist to imagine themselves entitled to have any sort of view on matters they knew absolutely nothing about and have these views published nationally and on the other side of the world. In fact, the leadership of some Aboriginal groups that were formed with State government funds to oppose the policies of the TAC were a Mansell and a Smith, and so were clearly related to TAC identities. Their Aboriginality has never been doubted by TAC. That's not the case with some of their colleagues, some of whom have come up with the most incredible stories of their Aboriginal family background, ignoring for example, the accounts of previous spouses that they never considered themselves Aborigines during marriages of several decade's duration.

I would never have foreseen that the first few years of our organisation's achievement in bringing together the Aboriginal community statewide would then be used against us with such potentially damaging consequences. But we've seen how historians and social commentators have taken it on themselves to pass judgement on our attempts to ensure Aboriginal resources are used for Aboriginal people as being prompted by greed or power. Many politicians seem to have bought into that same narrative also.

As a side note: We did have and continue to have close friendships with people who have been involved in the Aboriginal movement for decades whose Aboriginality we had to question when evidence came to light that they had been mistaken in their identification. Close friends were treated the same as total strangers: they were asked to explain the discrepancies and when that proved impossible, they could not be regarded as Aboriginal even though they remained friends and colleagues if they chose to do so.

HISTORIANS

A similar situation unfolded with historians as with social commentators. Too often, our history is penned by non-First Nations writers who, despite their lack of lived experience, claim or assert a connection to our heritage, thereby continuing the cycle of appropriation and silencing our true voices. For example, the esteemed historian Henry Reynolds publicly declared he has Aboriginal ancestry although his family chose not to claim Aboriginal identity based on that ancestry. I refer you to the article in the Sydney Morning Herald of 26 August 2005 entitled *A Real Nowhere Man*. Reynolds had concluded that his grandmother Margaret was an Aboriginal woman, not from Tasmania, who had decided to pass as white and create a new life in Tasmania because 'What could you do when everyone was convinced you were either a Stone-Age primitive or a mixed blood of degenerate character?' (Sydney Morning Herald, 26 August 2005 https://www.smh.com.au/national/a-real-nowhere-man-20050826-gdly85.html).

The newspaper article is not detailed enough for anyone to form an opinion about the factual basis for concluding there must be Aboriginal heritage when there's a gap in the official records. But this is the same story told by the many in Tasmania who came to imagine themselves to have Aboriginal ancestry, often in the face of all evidence to the contrary.

What set the historian Professor Lyndal Ryan apart from others, was especially in the early days her genuine effort to engage with Aboriginal people about her work and seek our opinions. Her involvement went beyond mere discussions or seeking support for funding applications, which remains common today. She was among the very few, if not the only author, to genuinely engage with the Aboriginal community to the extent that she donated the royalties from her book sales to the Aboriginal community.

We have seen so-called historians using their publications to re-write history and criticise Aboriginal organisations without giving them a right of reply, for example Ian McFarlane. It's perhaps in the nature of those who identify as historians to claim they've discovered new facts, have new perspectives, or even have found a disputed footnote somewhere, who seek to create a name for themselves through their writing, like Keith Windshuttle. The proliferation of 'new histories' in recent years has been bewildering. In a short period, entire books were published about specific Aboriginal individuals, with some claiming to reveal never-before-known facts. However, it remains unclear what these new facts actually are! Meanwhile, these claims have sold books, granted the writers access to materials in academic institutions, and secured grants for international study. No wonder there is growing frustration and claims of white privilege, especially from younger Aboriginal people.

To conclude this section, I will quote from the Monash University Publishing book, *Me Write Myself*, published in 2017 (https://publishing.monash.edu/product/me-write-myself/):

> *First Nations scholars and communities may convincingly argue that white historians have no place at all writing First Nations histories. Historians have been a major source of colonisation, and First Nations people … have been dispossessed time and time again by this means. … However, the Wybalenna story is foundational to Australian and global colonial history.*

And so the author Leonie Stevens goes on to write her book about our people. Most of it is a retelling of the usual histories but at least some of it deals with the writings of those Aborigines exiled to Flinders Island in the 1840s. As usual, the sources reveal the George Augustus Robinson's journals and the Colonial Secretary's Office as the major sources of information and there is the usual cross-referencing of the works of fellow academics including Henry Reynolds who has been behind much of the retelling of the invasion stories in recent years.

CLOSING THE GAP

The *Closing the Gap* campaign is based on a National Agreement, entered by every single government in Australia, including the Local Government Association. To recap briefly, the National Agreement contains four priority

reform areas and 19 social targets. It's the priority reform areas that should result in improved relations and improved social conditions. They are about how the work is to be done, rather than the list of what is to be done. The priority reform areas are:

- Shared decision making of Aboriginal people with governments,
- Developing formal Aboriginal community-controlled sectors to deliver services to the Aboriginal community,
- Systemic and structural transformation of mainstream government organisations to improve accountability and respond to the needs of Aboriginal people,
- Shared access to data and information to support the achievement of the first three priority areas.

Progress on achieving these reforms has been patchy, at best. In Tasmania it remains impossible to obtain reliable data as a basis for assessing outcomes.

Here's an example of the unnecessary paperwork and time wasting that keeps public servants employed and Aboriginal organisations bogged down in bureaucracy: we were late starting a major project and had underspent our funding at the end of the financial year. It was agreed the contract should be extended for 6 months. To make this possible required a formal deed of variation of the grant deed and eight pages of written contract from the Department of Premier and Cabinet. No evidence of systemic or structural change there!

Funds historically paid to the charitable sector are meant to be considered for transfer to the Aboriginal community-controlled sector. In Tasmania they have not yet been able to identify what organisations and entities receive what funds intended for Aboriginal advancement. They've accepted that Aboriginal organisations achieve better results for Aboriginal people but there is one reason after another for delaying the transfer of funds.

VISION FOR THE FUTURE

The *Voice* as a vision for the future is no longer an option. It was only ever intended to create an advisory rather than a decision-making body. The problem has never been a lack of advice to government; but a failure of governments to accept and act on that advice. Constitutional change is similarly 'fraught'. The wasted effort of the *Recognise* campaign saw some additions to the Constitutions of some Australian States, including Tasmania. Despite all the good intentions, those changes have made no difference to anything, even symbolically. Even worse, millions of dollars were wasted on the *Recognise* and the *Voice* campaigns, with the net result being that racism has worsened, and many Aboriginal communities are still in abject poverty.

As a personal anecdote: I tried to engage a Tasmanian politician recently about the impossibility of keeping up with the task of removing racist comments from our social media including stories about Aboriginal parents and children enjoying a kids disco during NAIDOC week. The reply was there was nothing the government could do and removing hateful remarks from their own social media is also a task of politicians. I didn't know where to start in explaining why that is so different to the experience of Aboriginal parents and their youngsters trying to celebrate their great NAIDOC experiences online and being hit by an onslaught of haters denying their very existence and worse. I'm sure the audience today understands the impossibility of *Closing the Gap* while this level of explicit racism continues to exist and to be so openly expressed.

The recent change to the make-up of the Tasmanian Parliament gives added impetus to the idea that Aboriginal seats in Parliament hold significant potential to force real change. The combination of minor parties and independents who can align with a major party to force change in government policy is solid evidence this model can work. A major obstacle is that this would involve at least tacit approval of the sovereignty of the invaders. So, is it realistic that we continue to advocate for Aboriginal nationhood and Aboriginal sovereignty rather than making an accommodation with the inheritors of the spoils of invasion?

It is outside the scope of today's lecture to examine the details of how Aboriginal sovereignty has been treated in this country and the international law implications of nationhood. What we can see all around us though is the adjustability of our people in surviving in this colonial environment while holding fast to our long-term aspirations. We must not give up on Treaty nor on demands such as the abolition of celebrating the 26 January as Australia Day. Even if Treaty is not undertaken as an international Treaty between equal States, Treaty is a useful mechanism for ensuring the terms on which Aborigines agree to co-exist with the mainstream and that it is negotiated with respect given to Aboriginal self-determination and co-existence.

My hope is that whatever political environment we are living in, more of us will be speaking our language *palawa kani* and many more of us will know our history including recognizing the significance of places like Grindstone Bay as they pass by on the way from Nipaluna to Wukalina. More will know the names of our warriors like Tukalunginta (aka Tongerlongeter, King William) and Kikatapula (aka Kickerterpoller, Black Tom, Tom Birch) and will recognize names like George Meredith, Amos, Gatehouse and Buxton as more than early east coast settlers.

My hope is that the younger generations won't give up. It must be tempting to turn away from the political situation and adopt a lone cultural, artistic, or even entrepreneurial stance to well-being as an Aboriginal person in Lutruwita. There are people in our community making very significant contributions in those spheres; and I congratulate them. I continue to believe, however, that the best hope for the future of our people is a very strong Aboriginal community-controlled sector. There are many reasons for that, not least being ensuring accountability to the Aboriginal community.

Thank you for listening: nayri nina-mapali.

(accepted 7 October 2024)

HISTORIC DOCUMENTATION OF CONTINENTAL DRIFT

by John K Davidson

(with seven figures)

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The concept of continental drift started with the Ancient Greeks. Translation of part of Strabo's Ancient Greek manuscript based on Eratosthenes' mapping of sub-continental scale, geographic and geologic units which he named 'sealstones', led to the discovery that he had employed a successful, rectangular co-ordinate, mapping method. As early as c.240–220 BCE the detail of his data produced the first evidence of the continental drift of Italy from Corsica/Sardinia. Some 22 centuries later, Professor SW Carey convened an international symposium in Hobart in 1956 where he presented a global, hemispheric projection and included more detail of the same Mediterranean area. These comparisons, together with Ortelius' claim in 1596 from a partly curved global Mercator projection that, 'it was as if the Americas were torn apart from Africa/Europe', provided a sequence of shoreline co-ordinate gathering peaks that transferred to evolving mapping methods and proved continental drift.
Key Words: continental drift, Eratosthenes, sealstone mapping, Ortelius, SW Carey, global tectonics, Tasmania.

INTRODUCTION

What is continental drift? If all seven continents and continental fragments are correctly fitted back together at their matching continental shelf edges (the 200 m isobath or more precisely at the 2,000 m isobath), they would form a single continent, then the process which caused each continent to break away to its present position is termed 'continental drift'. The starting point of recognising continental drift was the first map constructed by Anaximander (600–c.546 BCE), the Greek philosopher, who imagined the Oikumene (Greek term *Oikoumene* meaning the known world) to be shaped like a cylinder, the top diameter of which being about three times the cylinder height, approximating the shape of a thickened coin (fig. 1). Eratosthenes would later (c.240–220 BCE) then successfully demonstrate some separation in the Mediterranean Sea between two of the three defined Anaximander continents of Europe and Libya (Africa).

This paper interprets three significant reassemblies of continents which have evolved over the past 2,600 years of recorded history of mapping during the past one millionth of the four billion years of Earth history, or the last 1.0% of the existence of *Homo sapiens*.

ERATOSTHENES' (276–195/194 BCE) MAPPING OF CONTINENTAL DRIFT, C.240–220 BCE

Eratosthenes, the ancient Greek polymath (fig. 2A, 2B), created his Ancient Greek map of the known world in c.240–220 BCE while working at the Library at Alexandria. This map was later reconstructed by the Greek historian Strabo c.18 BCE, while also working at Alexandria in Greek-occupied Egypt, the original map having 'vanished to history' (fig. 2; nineteenth century reconstruction by Bunbury (1883), Hamilton & Falconer 2014). In 2011, C McPhail translated the Eratosthenes map and sealstones text, also via Hipparchus (c.190–c.120 BCE), from Strabo (18–7 BCE,) as the focus of his Masters' thesis (McPhail 2011).

The relative location of cities, detail of major rivers and the three rows of symbols depicting the Taurus Mountains had progressively added details to Anaximander's map and attest to almost four centuries of geographic traditions. The blue strip parallel with the shoreline of West Libya (now Africa, fig. 2A) was established during the voyage of Hanno the Phoenician c.600–595 BCE and supported the encircling ocean concept in figure 1.

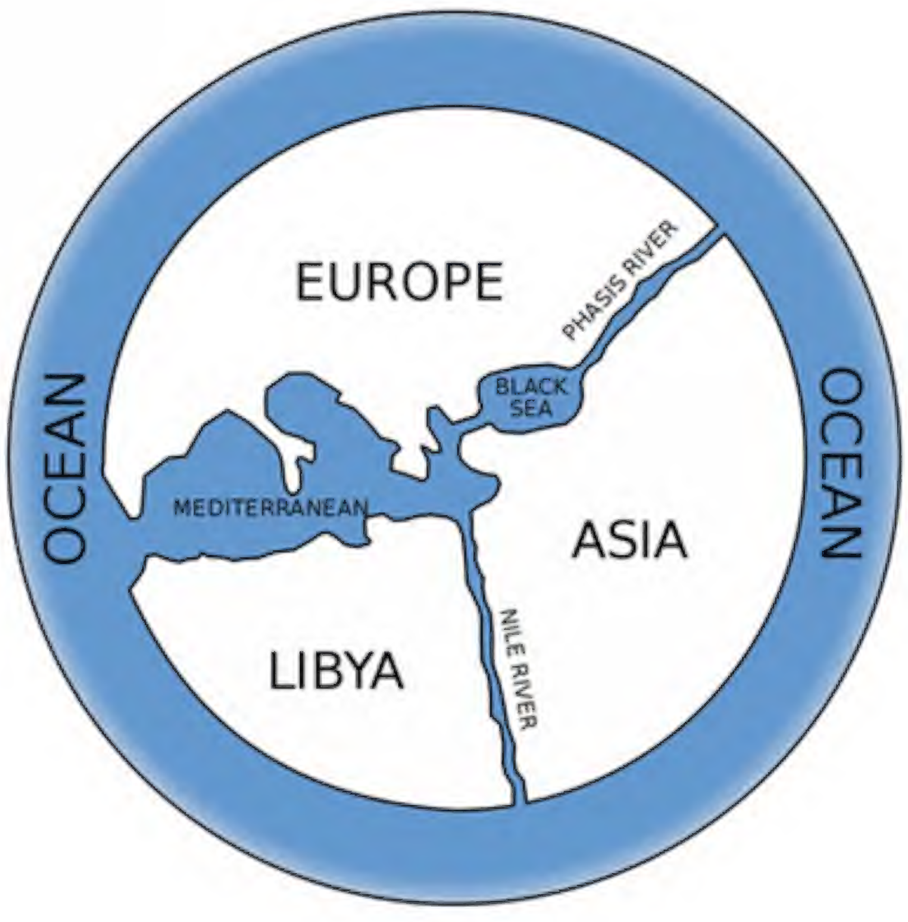
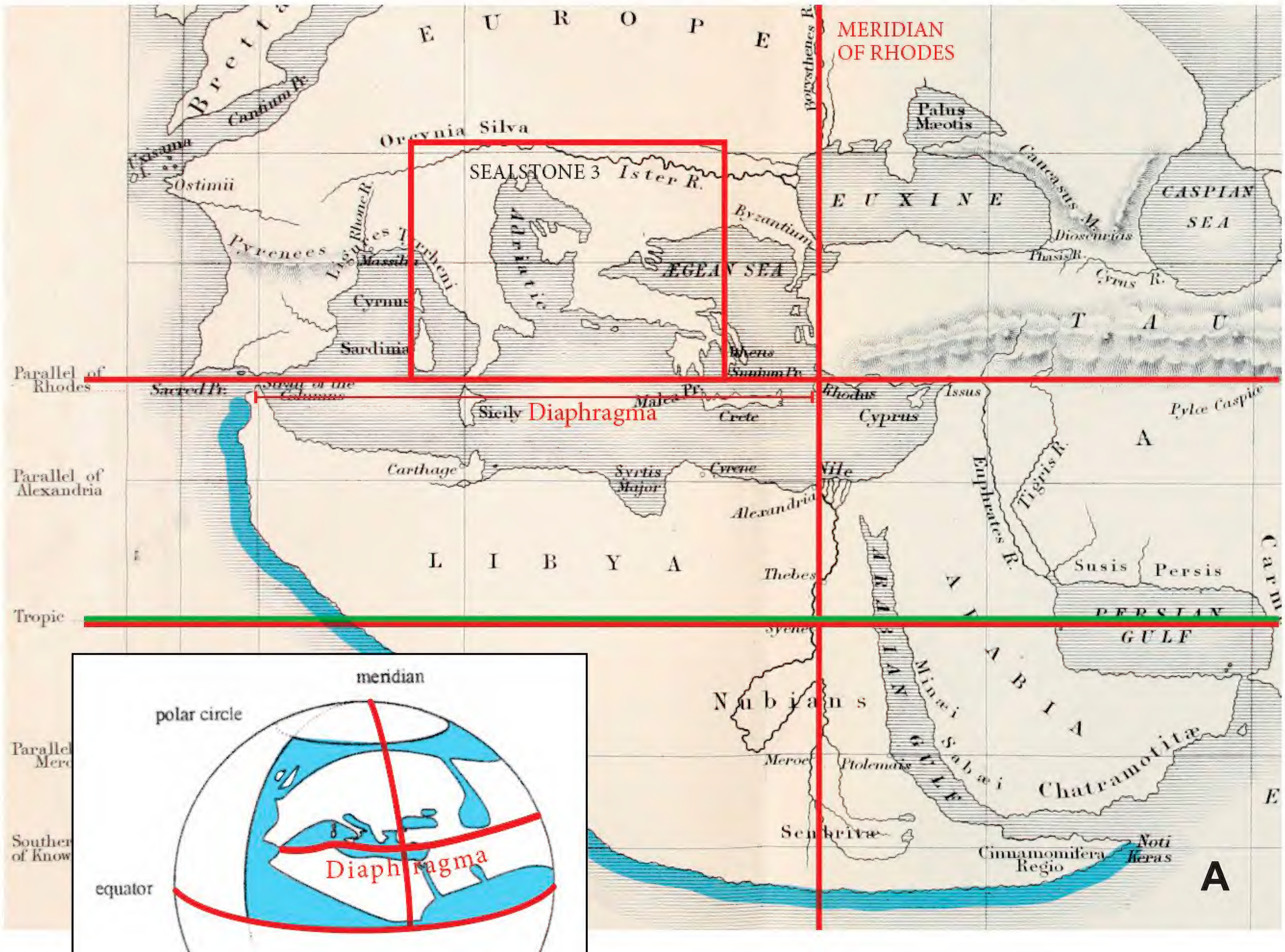
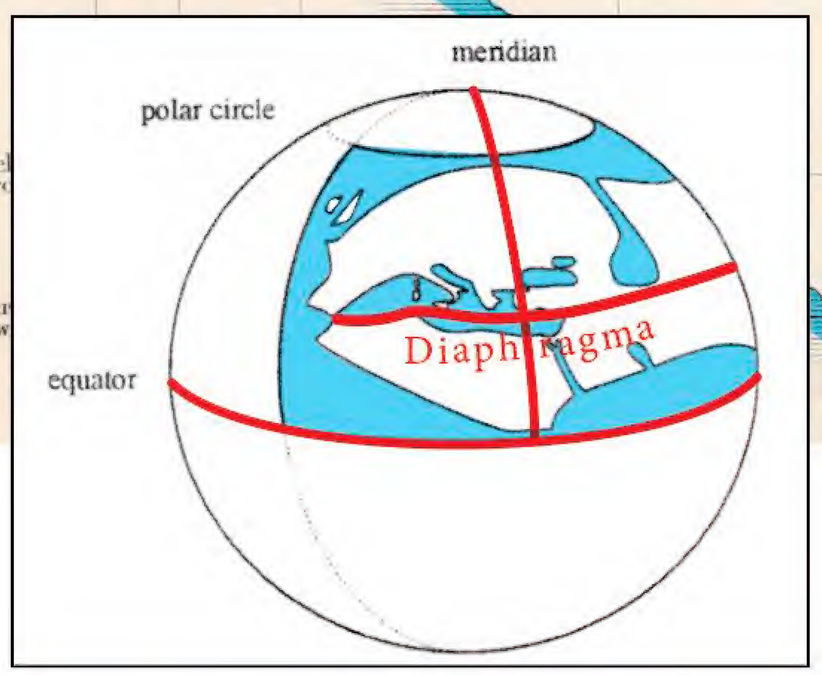
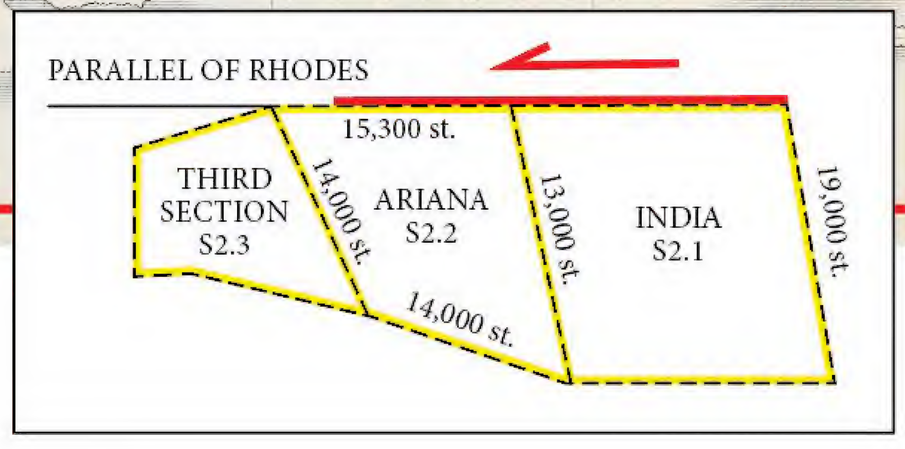


FIGURE 1 — Anaximander World Map (Open licence from *World History Encyclopedia*. https://www.worldhistory.org/image/18224/anaximander-world-map/).


MERIDIAN OF RHODES
SEALSTONE 3
Diaphragma
Parallel of Rhodes
Parallel of Alexandria
Tropic
EUROPE
LIBYA
ARABIA
EUXINE
CASPIAN SEA
AEGEAN SEA
PERSIAN GULF
Nubians
Gedrosia
Ichthyophagi
Chatramotitæ
Cinnamomifera Regio
Noti Keras
Sicily
Carthage
Crete
Cyprus
Rhodus
Byzantium
Palus Mæotis
Susis
Persis
Sacred Pr.
Thebes
Meroe
Ptolemais
Alexandria
Syrtis Major
Cyrene
Scenitæ
Sardinia
Ostimii
Massilia
Issus
Pylæ Caspiæ
Euphrates R.
Tigris R.
Nile R.
Dioscurias
Phasis R.
Cyrus R.
Ganges R.
Palibothra
Arachosia
Coniaci
Sembritæ
Meridian of Alexandria
Equator
A


meridian
polar circle
Diaphragma
equator

Pytheas 310 BCE
Earth Tilt 23.5°
PARALLEL OF THULE
SEALSTONE 3
SEALSTONE 1
SEALSTONE 2.1
Diaphragma
Diacaerus c.295 BCE
EQUATOR
Parallel of Rhodes
Tropic
Parallel of Alexandria
Parallel of Meroe
Southern limit of Known World
EUROPE
LIBYA
ARABIA
INDIA
EUXINE
CASPIAN SEA
PERSIAN GULF
Nubians
Gedrosia
Ichthyophagi
Chatramotitæ
ERYTHRÆAN SEA
NORTHERN OCEAN
SCYTHIA
SOGDIANA
BACTRIA
Cyprus
Rhodus
Byzantium
Palus Mæotis
Susis
Persis
Sacred Pr.
Thebes
Meroe
Ptolemais
Alexandria
Carthage
Cyrene
Scenitæ
Sardinia
Ostimii
Massilia
Issus
Pylæ Caspiæ
Euphrates R.
Tigris R.
Nile R.
Dioscurias
Phasis R.
Cyrus R.
Ganges R.
Palibothra
Arachosia
Coniaci
Sembritæ
Meridian of Alexandria
Equator
2.4
2.3
2.2
c. 19,000 st.
B


PARALLEL OF RHODES
15,300 st.
THIRD SECTION S2.3
14,000 st.
ARIANA S2.2
13,000 st.
INDIA S2.1
19,000 st.
14,000 st.

The Phoenicians were an amalgamation of two cities in the present Lebanon–Israel area c.1200 BCE and were noted for supplying cedar logs for shipbuilding around the Mediterranean resulting in the settlement of Carthage (Tunisia, fig. 2A, lower, centre, left) in 814 BCE. They probably had papyrus shoreline and city maps since they knew the significance of the Pole Star for navigation; however, no maps have been found. During this period, tin was arriving, probably into Carthage from the North Atlantic east coast and, likewise, gold from camel trains via north-central Africa and Cerne on coastal northwest Africa (fig. 2B, lower left).

Homer (800–c.746 BCE) probably used a map expanding from the Aegean Sea as the setting of his poems which famously focussed on the ten-year Trojan wars of 1183 BCE (based on Eratosthenes' calculation). The location of Troy on the Meridian of Rhodes (fig. 2A) is now an archaeological site but no maps have been recovered. As early as 1800 BCE the Mycenean Greeks of Athens and of the Peloponnese were trading with the Minoans of Crete adjacent to the south, who were sailing by night using the direction of setting star constellations to trade with Alexandria at the mouth of the Nile. The Minoan pilots were thought to carry the sequence of the setting constellations in their minds, effectively a 'map' of the direction to Crete 4,000 years ago.

From 332–320 BCE, Anaximander's Oikumene grew predominantly eastwards from the Phasis River to India (from fig. 2A to fig. 2B) due to the conquests of Alexander the Great. In 310 BC, Pytheas left Marseilles to better define the northern sector of the Oikumene. He circumnavigated Britain and on to Thule (Iceland, fig. 2B, top left) or, more likely, the Lofoten Islands of Norway. In both instances, at the winter equinox the sun was not visible. Pytheas was at the now Polar Circle and had measured the 23–24° Earth tilt of the geographic North Pole axis (fig. 2B, top left). Fifteen years later another Greek scholar, Dicaearchus (c.295 BCE), drew a straight, west-east line, from the Straits of the Columns (Gibraltar or Pillars of Hercules), east 'below' the volcano- and earthquake-prone Italian toe and Sicily, and on to Rhodes where the Colossus had been toppled by an earthquake five years after the birth of Archimedes and four years before Eratosthenes. Dicaearchus called the line the 'major parallel' or the Diaphragma (shown by the red horizontal line on fig. 2A and 2B, centre). He then aligned a perpendicular or north-south 'meridian' through Rhodes.

About 240 BCE Eratosthenes extended that perpendicular south through Alexandria, sub-parallel with the Nile River to Syene, a distance of 5,000 stadia (c.800 km). He realised that at Syene on or about 21 June the sun would be directly overhead and, if he was in Alexandria looking down a well or at the shadow of a vertical pole, the Earth was spherical if the pole, or the well, cast a shadow to the north and if they didn't, then the Earth was flat. A shadow of 7.2° was cast which is 1/50th of a 360° Earth with a circumference of 250,000 stadia also with a radius very close to 40,000 km, which we use today**.** He projected his full map onto his new spherical earth (fig. 2A, inset), an historic mapping triumph. His map shows the spread of his parallels and meridians to form a rectangular grid of east-west latitudes and north-south longitudes, now referred to as a 'Mercator' rather than an Eratosthenean map projection**.**

Eratosthenes 'sealstone' mapping (c.240–220 BCE)

Eratosthenes extended the geologically active Diaphragma along the southern edge of the three rows of mountain symbols of high Taurus to the Himalayan Mountains, as a single geologic/geographic unit he termed 'Sealstone 1', possibly implying some legal or trading notion to the rock (fig. 2A and 2B, east). He showed India as a rhomboid or an east-west, left-sheared square and called it 'Sealstone 2.1'. Ariana as 'Sealstone 2.2' is possibly more similarly displayed by having an approximate side-length of the order of 14,000 stadia on a skewed square. The overall point was that the topography of 'Sealstone 2.4', which reached Alexandria on the Mediterranean Sea, was less than 2.3, less than 2.2 (and less in height than Sealstone 2.1, and Sealstone 1) emphasising gradations of vertical uplift. Strabo was also impressed with this because he lived in western Türkiye and had attributed the seashells in the rocks of Sealstone 1 to uplift of a previous sea (indeed from the shorelines of the Tethys Ocean to the Taurus Mountains, to the Himalayas).

The third 'Sealstone 3', the promontories of Italy, Liguria (Corsica/Sardinia) and the Peloponnese of Greece within the red rectangular boundary in the central Mediterranean (fig. 2A and 2B), indicate Eratosthenes was more interested in this sealstone in the plan view of the widening blue areas of the opening Tyrrhenian and Adriatic seas, than of vertical uplift of Sealstones 1 and 2. Posidonus (135–51 BCE) plumbed the Tyrrhenian Sea by dropline and found it was far deeper 'than any other' (in the northern Mediterranean): in excess of 12 stadia or 2 km deep – actually 4 km today.

Comments on Eratosthenes' promontory work, reported principally by Hipparchus (c.190–c.120 BCE) and derived by Strabo (64/63 BCE–24CE) between 18 and 7 BCE were then translated by McPhail (2011). Eratosthenes had correctly deduced that stretching had caused sinking of 12 stadia and the Tyrrhenian area to extend by 1,200 stadia (or 200 km) from southern Sardinia to the 'ankle' of Italy which had rotated Italy eastwards relative to Corsica/Sardinia**.** Hipparchus also reported the Peloponnese had separated east from the 'instep' of Italy shown by the longer

FIGURE 2 — Nineteenth-century reconstruction of Eratosthenes' map of the known world c.240–220 BC (from Bunbury 1883). **A** Western half of map, inset (after McPhail 2011, fig. 3.2): Zimmerman's reconstruction of Eratosthenes Oikumene framed by the quadrilateral (fig. 2B) and projected onto the three-dimensional surface of the spherical earth; **B** the full Bunbury map of Eratosthenes, top inset: etching of an ancient seal identified as Eratosthenes; bottom inset (after McPhail 2011, fig. 4.3): showing a schematic, geometric representation of India, Ariana sealstones and the third sealstone.

half-arrowhead from the Peloponnese, about 6,000 stadia (1,000 km larger than the 'known distance' of Alexandria to Syene); in total, some 1,200 km of westward movement along the northern side of the Diaphragma, relative to no movement on the southern side.

MacPhail did not mention the word 'rotation' of Italy from Liguria. However, Eratosthenes would have realised two moving blocks could only move parallel with each other along the Equator or a great circle of a sphere; moving towards either pole or in other directions would cause them to rotate about a pole, as in the fixed point of a drawing compass. Both the Tyrrhenian and Adriatic seas open and widen in a 'V-shaped' manner from north to south indicating a pole of rotation at the north head of their respective seas and imposing shears shown by the half-arrowheads along the Diaphragma fault. When Eratosthenes projected his map onto the sphere in the figure 2A inset, he probably recognised the curved form of the 'prime meridian' through Rhodes. And so may have Claudius Ptolemy (90–168 CE), the Greco-Roman of conic-mapping projection fame, also working at the Library at Alexandria, c.150 CE.

In the failing days of the Roman Empire, Macrobius (active from 399–c.450 CE) showed five horizontal 'Diaphragmas' or shears on his globe, apparently coinciding with northern and southern tropical and polar circle latitudes and the Equator (fig. 3), suggesting he extended the function of the Eratosthenes Diaphragma from a sheared and later compressed seaway to the dual role of horizontal, climatic-boundary seas which drained to the encircling ocean. The red Diaphragma in figure 3 was north of the green parallel of longitude between the Tempurata Nostra and the Perusta (Tropics). Hiatt (2007) said there were an estimated 150 versions similar to figure 3 before 1100 CE, many stemming from German monasteries, like the figure 3 sketch (c.1000 CE). The influence of Eratosthenes' sealstone method spanned 14 centuries until 1154 CE when a Chinese ship was sighted off Morocco, indicating spice and silk trade shipping west from the Indian Ocean may not have rounded southern Africa's Cape Town until then, and, more likely, had crossed from northeast Africa across the Sahara to the Mediterranean coast prior to that date via camel trains. By 1487 Diaz, the Portuguese mariner and explorer, provided competition from the Portuguese by reversing the shipping direction from the Atlantic to Indian oceans.

The Conclusions from McPhail's (2011) study of Eratosthenes include:

…the fragments of Eratosthenes' Geography, despite constituting only a small portion of the total work (three volumes), are predominantly cartographic in nature, conveying a good spread and depth of information regarding how the Oikumene should be drawn.' (p. 171).

Scholars have frequently expounded that Eratosthenes was one of the first and foremost proponents of scientific cartography. Earlier maps were often ethnologically driven, communicating a Hellenistic worldview in which the Greeks in the centre of the map were juxtaposed against the barbarian peoples of the periphery. By way of contrast, Eratosthene's parallels, meridians…and other cartographic systems are believed to have engendered a far more systematic and objective image of the world. (p. 171)

Pytheas, c.310 BCE voyage throughout northern and western Europe was so unique and influential that it would not be far off the mark to assert that Eratosthenes' knowledge of this region was driven almost entirely from On the Ocean… surveyed the Atlantic coastline as far north as the land of Thule… His observations of celestial phenomena in these regions shaped his depiction of parallels of latitude north of Massalia (Marseilles). (pp. 173–174)

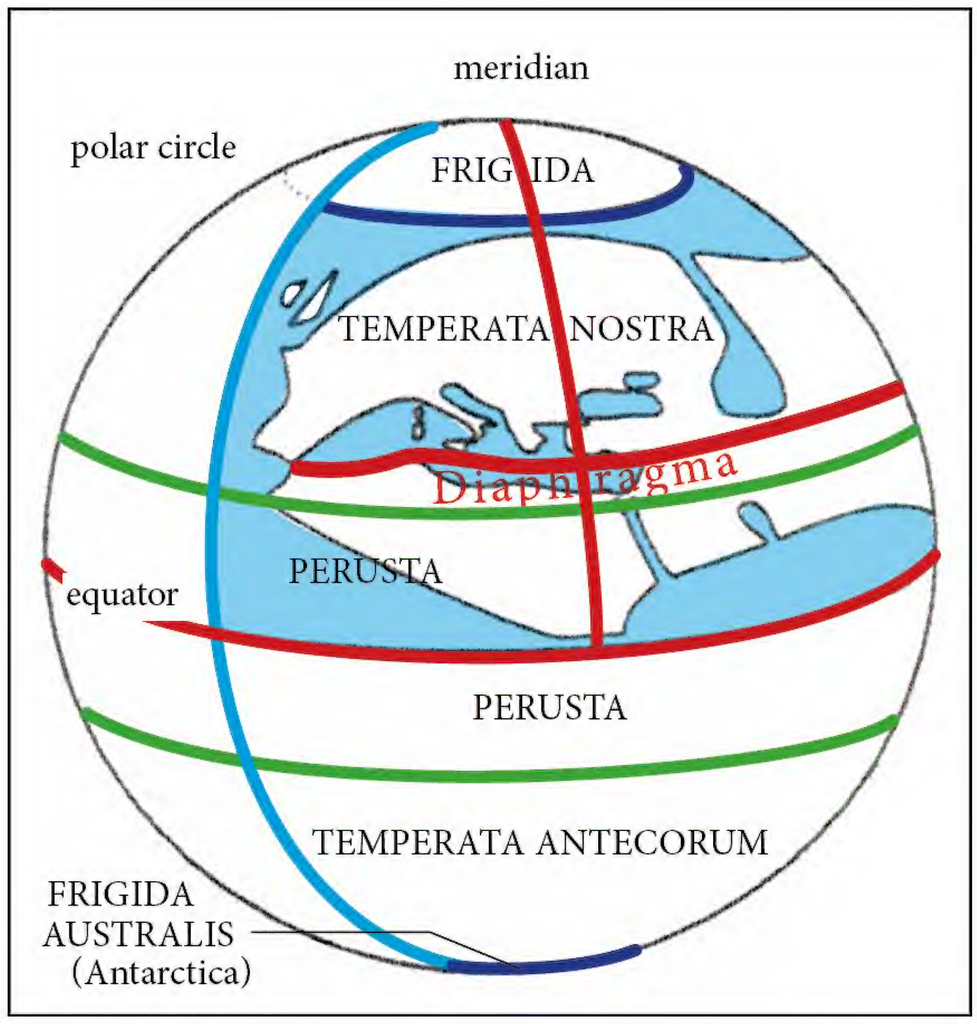


FIGURE 3 — After McPhail (2011, fig. 3.2): 'Zimmerman's reconstruction of Eratosthenes Oikumene framed by the quadrilateral and projected onto the three-dimensional surface of the spherical Earth' overlain by the author's sketch of climatic 'diaphragmas' from Hiatt (2007, p. 152).

Only a decade earlier, Alexander the Great's 'bematists or 'footsteppers' (specialists who measured distances by pacing) had combined on the ground measurement of distances with celestial readings. Pytheas is the earliest method of celestial coordinate gathering of shorelines that did not become prominent again until 1487, over 1.5 millennia later.

ORTELIUS (1527–1598 CE) CARTOGRAPHY OF CONTINENTAL DRIFT, 1596 CE

Trading-related sea battles increased, and shoreline co-ordinate number pairs also grew from 1487 to 1570 to meet the growing demand for Antwerp-based shore/coastline mapping. In 1569, Mercator published his famous rectangular grid of lines of latitude and longitudes. This meant his map began losing its area/distance-preserving qualities

at about 23.5° north, like Eratosthenes' map: the spherical globe to flat surface map challenge. Abraham Ortelius (fig. 4B), a commercial Antwerp cartographer, had accumulated many shoreline co-ordinates and published his map of the world in 1570 (fig. 4A) along with several others in the first world atlas.

Increased higher latitude-sailing required Ortelius to apply some Earth spherical curvature to his grid so he decreased the parallel or latitudinal length gradually from the Equator to about 60% of that at the poles (fig. 4B). His map looked like an elliptical racetrack rather than a rectangle and was a more multi-purpose map, which probably increased sales. He also regularly revised and updated his atlas with copies sold in Antwerp and London and probably elsewhere. In his reconstruction, Brazil fitted poorly into the Gulf of Guinea; however, the southwest and northwest African shoreline trends (fig. 4C) fitted well with their South American equivalents (fig. 4C) and the northwest African shoreline with that of the eastern USA. Ortelius' fit of Ireland/Britain against southern Greenland was impressive without the intervening Iceland, and Spain did not fit against Labrador. The northwest of Norway and East Greenland fit, given sparse co-ordinate data near the Atlantic pole of rotation, was surprisingly good; however, he could only make his map lie on a flat table if he chose a west-east Europe-Asia/Africa boundary and made a cut along it, from the coast of northern Africa/Mediterranean and then guided his cut using his excellent drainage mapping to the Persian Gulf and then follow the shoreline east to the Pacific as in figure 4C. His cut opened a large, eastwards trending and widening, irregular 'V'-shaped gap.

The author has no evidence Ortelius made such a physical reconstruction, nor did he know he was essentially copying Eratosthenes by probably cutting along Dicaearchus' Diaphragma shear. Neither could he have known of Carey's twentieth-century Tethys gap, resulting from his 'V'-shaped cut. He had only two years to provide some evidence as he died just two years later in 1598. There was another method. His atlas also showed he had to remove Iceland from between the Greenland and Norway fit to be able to state in 1596: 'it was as if the Americas were torn apart from Africa/Europe'.

Ortelius included the scholar Gudbrandur Thorlákssons's (1541–1627 CE) wonderfully detailed and illustrated 1585 map of the linear volcanoes and lava-fields of Iceland (figs 4D and 4E) in his atlas of 1595 (Ortelius & Vedel 1595). Since Viking settlement of Iceland in 870 CE (after 'Thule' of Pytheas 310 BCE), a complete record of active volcanoes has been maintained. Hekla (fig. 4D, inset) is a 5.5-km-long volcanic fracture volcano which is active along its length during major eruptions. Hekla is almost 1,500 m high, 100 km east of Reykjavik and has erupted more than 20 times between 1104 and 2000 CE, and Thorlákssons may have seen it erupt as depicted on his map. Figure 4D shows the red dashed line of Reykjanes Ridge (now the onshore extensional, separating part of the Atlantic Ocean Ridge and its red dotted continuation to the north). The activity at the Hecla section in c.1585 therefore postdates the initial continental breakup in the area between Greenland and the Scottish Hebrides, which enabled Ortelius to leave Iceland out of his mental reconstruction of the North Atlantic when making his simple statement of 1596. It appears Ortelius knew over three centuries earlier than Carey, that the oceanic ridge was probably the then current focus of separation between the continents. His cartography also told him the numerous volcanic islands emanating from the expanse of the Atlantic's volcanic seafloor were sampling the Earth's molten interior. And Thorlákssons's active, linear fracture volcanoes on the Reykjanes Ridge to Hecla were uniquely located approximately midway between the granitic continental crust of Greenland and the Scottish Hebrides. Clever deductions, as he worked diligently at his trade, had guided him.

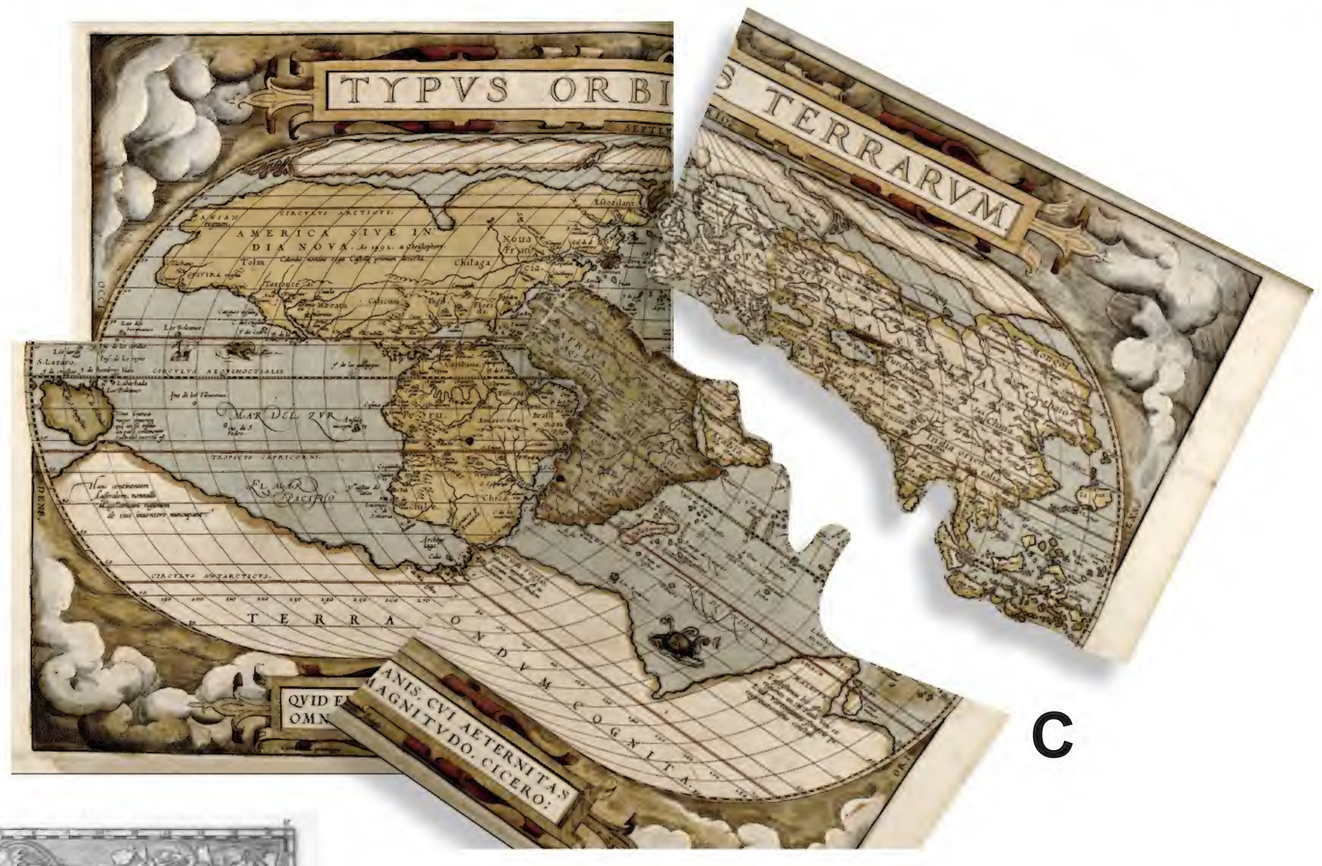
SW CAREY (1911–2002) SPHERICAL MAPPING OF CONTINENTAL DRIFT, 1958

Samuel Warren Carey (1911–2002), Professor of Geology at the University of Tasmania from 1946 until 1976, was recognised internationally as a controversial expert in global tectonics. An early believer of continental drift, many of his ideas were formed during field work carried out in the (then) Territories of New Guinea and Papua (Carey 1938, 1954, 1955; Baillie 2021). Carey was unaware of the work of Ortelius and Eratosthenes. In the opening paragraph of his 1958 symposium paper, Carey paid tribute to Alfred Wegener's 1912–1929 work on continental drift: 'Wegener worked out the broad outlines of continental drift….. but my picture of the assembly does not differ greatly…. and others have improved on details, but apart from the dissociation of Pangaea into Laurasia and Gondwana [fig. 5C] … the fundamental picture is much as Wegener saw it.' (Carey 1958, p. 177).

The third cartographically accurate map, at the time of reconstruction, was made by Carey in 1958 (fig. 5). Carey (fig. 5A) used two spherical methods. In the first he formed plastic sheets over a 30-inch (75-cm) globe (fig. 5B), and in the second he made stereographic projections (figs 5D, 5E) of the 'land hemisphere'. In both methods he matched opposing shelf edges, the 200 m isobath (fig. 5D) generally somewhat further seaward than the shorelines of Ortelius, and at the 2,000 m isobath if available (fig. 5E) closer to the actual break-zone of continental separation. These and other continental outlines were fitted to South America/Africa to form a complete jigsaw puzzle (fig. 5C). The unshown hemisphere (or reverse) was the Pacific Ocean. Apart from the South Pole and the resulting Arctic and Tropical circles, the flat plan, stereographic projection surface was lacking a cover 'picture' of a regional geologic map to confirm geology across adjacent pieces of the jigsaw puzzle reassembly (fig. 5C). The direct tracing fit at the shelf edge left a gap (fig. 5B) between southern South America and Africa which was comparable to the yellow area on the stereographic projection (fig. 5D), and likewise smaller yellow area to the northwest match, but both represented considerable advances over Ortelius and intervening sketches, such as those of Wegener.

TYPVS ORBIS TERRARVM
SEPTENTRIO
AMERICA SIVE IN DIA NOVA. An. 1492. a Christophoro
Noua Fran cia
Chilaga
Tolm
Tortuga
Caricuna
Florida
TROPICVS CANCRI
MAR DEL NORT
Caribana
Archipelago di S. Lazaro.
CIRCVLVS AEQVINOCTIALIS
MAR DEL ZVR
Amazo-nes
Brasil
Peru
TROPICVS CAPRICORNI.
OCEANVS AETHIOPICVS.
Terra del Fuego
Chica
Chile
Tartaria
Mongol.
Turchestan
Persia
Arabia
India orientalis.
Carthaio
China.
AFRICA.
Mar rubro
Mar di Sur
Lanchadel mare.
MAR DE INDI
MALEVA
CIRCVLVS ANTARCTICVS.
TERRA AVSTRALIS NONDVM COGNITA.
MERIDIES.
QVID EI POTEST VIDERI MAGNVM IN REBVS HVMANIS, CVI AETERNITAS OMNIS, TOTIVSQVE MVNDI NOTA SIT MAGNITVDO. CICERO:
A

B


TYPVS ORBI
TERRARVM
AMERICA SIVE IN DIA NOVA. An. 1492. a Christophoro
Noua Fran cia
Chilaga
MAR DEL ZVR
TROPICVS CAPRICORNI.
OCEANVS AE THIOPICVS.
CIRCVLVS ANTARCTICVS.
TERRA ONDVM COGNITA.
ANIS. CVI AETERNITAS
MAGNITVDO. CICERO:
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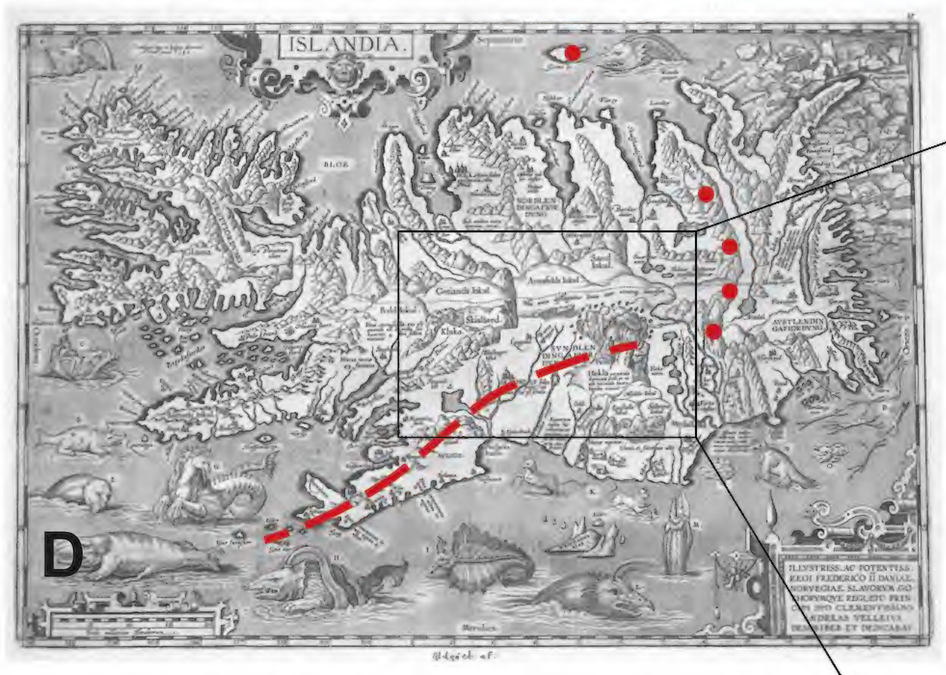
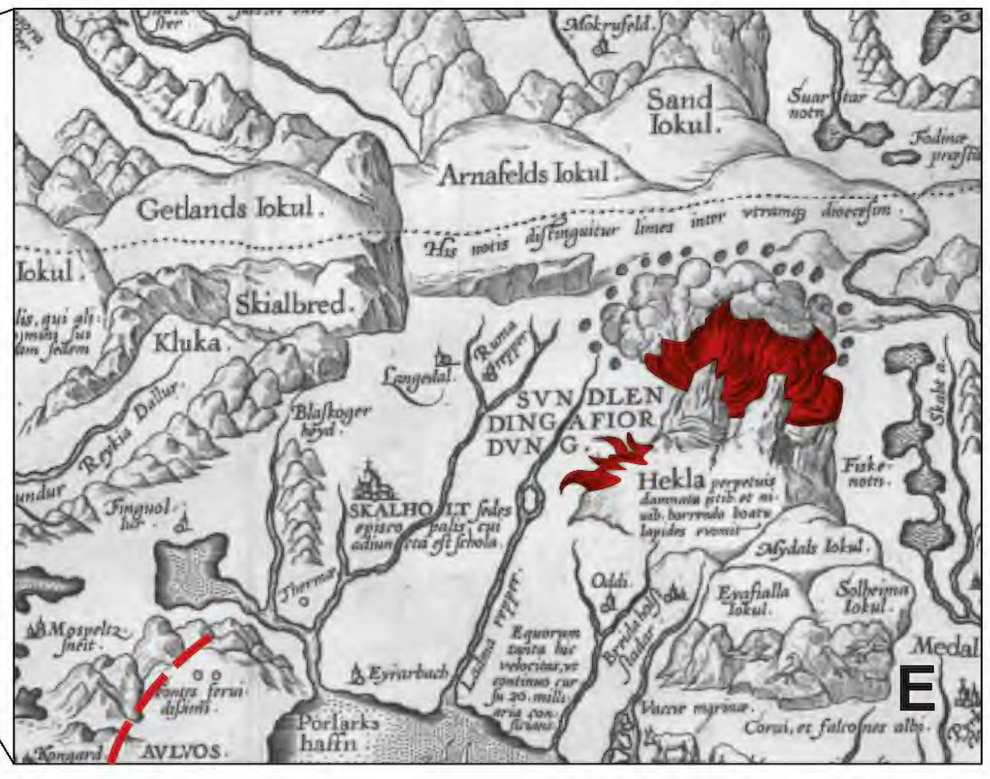

ISLANDIA.
D


Mokrufeld.
Sand Iokul.
Arnafelds Iokul.
Getlands Iokul.
Iokul.
Skialbred.
Kluka
Langedal.
SVNDLEN DINGA FIOR DVNG.
Hekla perpetuis flammis etiã et nunc horrendo boatu lapides evomit
Fiskenæs.
Mydals Iokul.
Oddi
Eyrafialla Iokul.
Solheimer Iokul.
Medal
Eyrarbach
Porlarks hafn.
AVLVOS.
E

As expected, the same South America/Africa match at the 2,000 m isobath (fig. 5E) was close to perfect and constituted the ultimate proof of continental drift; only the sediments of the post-drift Nile delta falsely infringed.

The cumulative reconstruction of the modern seven continents and smaller blocks left two large areas or 'gaps' (or yellow areas), the large TETHYS and smaller ARCTIC oceans in figure 5C indicating to Carey they were real and were either true oceans at the time of reconstruction on the present radius Earth or the Earth had expanded appreciably during the drift phase to the present. Carey devoted the last 11 pages of his symposium paper (Carey 1958, pp. 339–349) to explaining his reasoning for expansion, an endeavour which he pursued up to his death in 2002. More recent data are supportive of elements of his stance and will be considered in a forthcoming paper.

Carey (1955) wrote that one clear result of the orocline analysis is the recognition of the Tethyan Shear System (fig. 6A). What did he mean by an orocline? Many would have recognised folded rocks in vertical road cuttings, maybe metres in dimensions. These are generally formed by 'local' compression. However, Carey was interested in the very large folds in the horizontal surface plane, like folded mountain ranges, best appreciated from high above. Often, they involve a shearing component and can have dimensions of a thousand or more kilometres, indicating a globe-encircling deformation, a geologically distinctive feature, an ideal jigsaw picture on all continents it covered.

Figure 6A shows the deformational bends of folded mountain belts and anticlockwise rotated blocks, consistent with left-shear-offsets, shown in red. He described those offsets during the symposium in 1956: 'South America has been moved 1,000 km east with respect to North America. Africa has been moved east some 1,100 km with respect to Europe. Australia has been moved more than 3,000 km with respect to Indo-China' (Carey 1958, p. 340) (and a further 5,000 km with respect to Tonga/New Zealand). Effectively the Tethyan Shear was an east-west roller bearing between the two hemispheres, the Northern 'Laurasia' lagging the Southern 'Gondwana', which was relatively advancing.

The Mediterranean oroclines were geologically illustrated best exactly where Eratosthenes may have noticed their topographic expression, in the western Mediterranean (fig. 6B). Carey combined rock-type description from legends of the component, regional European geologic maps and constructed a 'relative timing of events', grey and black, oldest (pre-drift, industrial revolution coals of northern Europe), through pink, purple and blue, the Tethys and drift margin rocks, and the author moved the orange unit from the middle to the top of the section (youngest compression and sheared oroclines – see fig. 6B, right). Carey then 'unwound' or unfolded and essentially straightened to the recent pre-orange shape and removed the above 1,000–8,000 km of Tethyan Shear (fig. 6C). The folded core of some oroclines, such as the Ligurian Orocline in northwest Italy, can almost coincide with Poles of Rotation at centre left of figure 6B, which can be derived from Eratosthenes – that is, the northern Tyrrhenian and Adriatic seas opening. Both orocline and pole were probably created in environments of regional force acting on rocks with greater ability to flow or break (Carey 1954).

The explanation of the formation of the Tethyan Shear became the cornerstone of what was known as Carey's 'New Global Tectonics' (tectonics in Greek means 'building') in 1960 and by 1970 was altered to what we now call 'Plate Tectonics'.

Carey at Yale 1959–1960

There was very little headway with the science of continental drift in the nineteenth century. So little in fact that Allan Krill (2011) presented an essay on mid-nineteenth–early twentieth-century geologists as a contest between those against continental drift (i.e., 'Fixists') versus those for continental drift (i.e., 'Mobilists') as if it was a boxing match, and this makes very entertaining reading. Then Krill discovered SW Carey which caused him to add Carey in Chapter 10 in his revised book (Krill 2014, p. 252), in part as follows:

'10. From Continental Drift to Plate Tectonics

S Warren Carey's wake-up call to North American geologists (1959–1960)

After Chester Longwell retired as Professor of Geology at Yale and moved to California in 1955, the remaining professors at Yale University were less negative towards continental drift. Yale then made a curious contribution to the transition from continental drift to plate tectonics. In his autobiography, John Rodgers related how this came about:

> *'Sam Carey warrants a digression. He was a very innovative geologist, a maverick indeed and consciously so, with some very good ideas and others that most of the rest of us considered crazy. When I took my first sabbatical year (1959–1960) to go to Europe, Yale therefore had my salary to appoint a Visiting Professor. After careful consideration and consultation, and largely on the basis of a very innovative early article of his, we invited Professor Carey. Moreover, he made trips all over the United States and Canada, lecturing everywhere in his inimitable now-you-see-it-now-you-don't style (he had put himself through college by working as a magician) and North American geology has never been the same since. For he ended, once and for all, the condescending dismissal of the idea of Continental Drift that had characterized North American geologists. He also helped to lay the foundation for the theory of plate tectonics, "the new global tectonics" as it was called at the time, which revolutionized tectonic thinking during the 1960s. About 1955 Carey apparently*

FIGURE 4 — **A** Map from Ortelius *et al.* (1570); **B** Engraving of Ortelius open source from Wikipedia; **C** Reconstruction of Ortelius' map undertaken by the author; **D** Map of Iceland by Thorláksson, red dotted line showing the on-shore mid-Atlantic Ridge; **E** Close up of Thorláksson's map showing the Hecla volcanic fracture, red indicates lava.

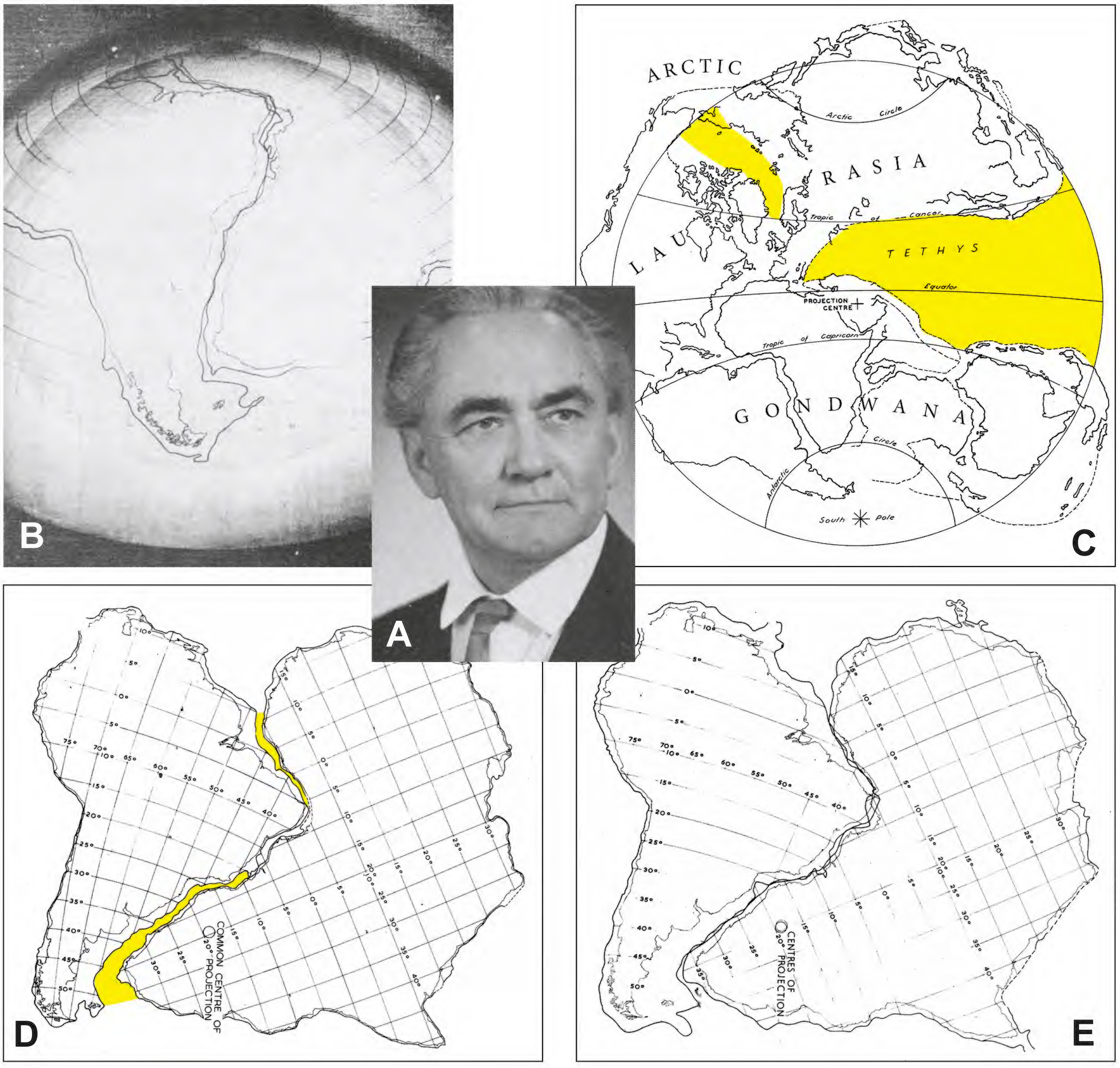


FIGURE 5 — Carey's reconstruction of continental drift. **A** SW Carey aged 65 (from Carey 1976); **B** Plastic sheet formed over a 30-inch globe; **C** Dissociation of Pangaea into Laurasia and Gondwana, yellow shows the Tethyan and Arctic gaps; **D** Stereographic projection at 200 m of continental edges, yellow shows gap; **E** Stereographic projections at 2,000 m edge showing almost perfect fit.

anticipated the new global tectonics in a manuscript that was rejected for publication as too speculative; I haven't seen it, but I'm told that it included both the creation of new crust at the mid-ocean ridges, forming the oceans, and its destruction or at least swallowing at belts of compression, where new mountain ranges are built. But curiously, in later years he reneged on the latter and recognized only the creation of new crust, and he became a strong advocate of the theory of an expanding Earth, going so far as to claim that its radius has about doubled in the last five hundred million years, implying of course that its volume has nearly octupled and therefore that its density then was nearly eight times what it is at present. It is this aspect of the theory that makes most of us unwilling to accept it, preferring to balance the creation of new crust, on which we agree with Carey, by the destruction of old crust, on which we disagree.

In any case, the best thing that I ever did for North American geology was to go away for a year, so that Carey could spend the year here.' (Rodgers 2001, pp. 194–195)

Carey's early adopters, 1972

The author joined Esso in 1970 and in 1972 Carey and I attended the first continental drift conference at Princeton, the first since 1956. Carey was re-acquainted with Lewis Weeks who in 1959 had advised the Broken Hill Proprietary Company to apply for oil exploration and production rights to the Gippsland Basin region, southeast Australia. Weeks confirmed Carey's Gippsland Basin structural predictions

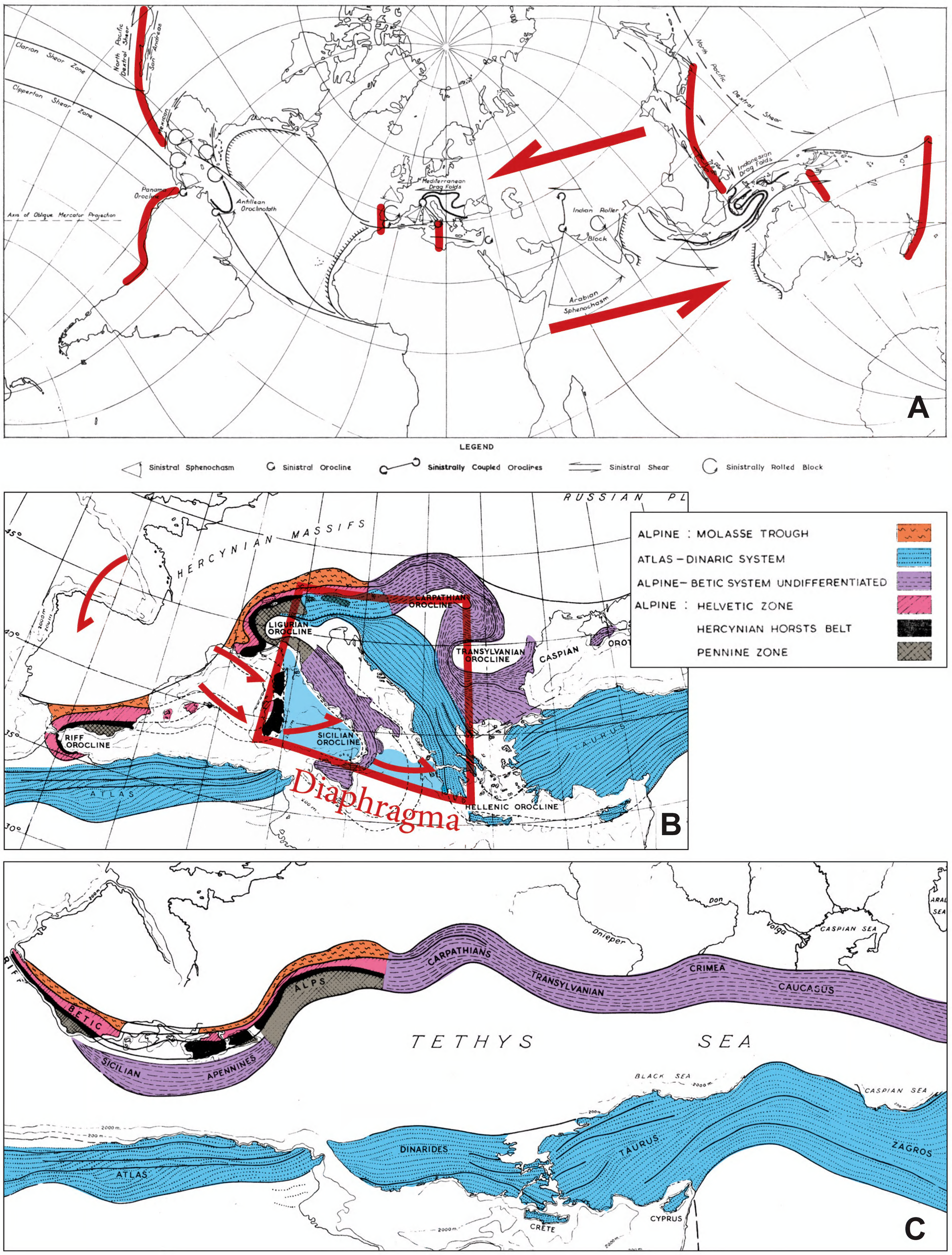


FIGURE 6 — Map of oroclines as described by Carey (1955). **A** Location of Tethyan Shear with arrows showing relative movement (Carey 1958, p.252); **B** Close-up showing oroclines at the bend at northwest Italy, legend gives geologic age, oldest at bottom (Carey 1958, p. 252);; **C** Straightening of folds in 6B to show the pre-Tethyan Shear (Carey 1958, p.253).

made in a sketch at Weeks' Connecticut home in 1959. Presumably Carey left the map with him. Three years after, the Gippsland, Bass and Otway basins acreage had been signed and the acreage granted by the government. Carey had a sense of being left out as Weeks gained a gross overriding royalty from the deal. Carey redrew that map (fig. 7) and presented it at the ANZAAS Conference in Sydney, 1963. The regional right laterally sheared offset is shown diagrammatically in the lower left of figure 7 and by the 100 km offset of offshore Gippsland Basin bathymetry with that of East Tasmania. Carey predicted the unknown offshore extension of the basin to contain northeasterly-trending anticlinal structures like '11 and 14' onshore. Weeks was aware of the minor oil production from the onshore during WWII. The offshore anticlines were confirmed by seismic data and successful drilling and significant commercial oil and gas fields were in fact discovered from 1965. The redrawn map was given to me and lies in a pink colour on silk (fig. 7). The same map by Carey (1986) was published in the technical papers from the Second South-eastern Australia, Oil Exploration Symposium. Weeks had retired as Esso's chief geologist and was the earliest Carey adopter apart from Rogers. In 1972 at Princeton**,** Weeks led a standing ovation for Carey joined by other oil company explorers whom Carey had met in 1959–1960.

DISCUSSION

Sealstone versus orocline

Eratosthenes used the 'sealstone' for differentiating the height and distribution of mountains to establish vertical movement of rocks as an indicator of uplift (by push or compression) and he used bathymetry as a measure of the sinking of the Tyrrhenian Sea to establish horizontal movement of pull or extension. He effectively recognised the Diaphragma as a side-by-side movement with Sardinia/Italy/Greece (the Peloponnese), a separation zone on the northern side and no evidence for separation on the southern. Over two millennia later Carey used the same push and pull indicators of force (or stresses) and the Diaphragma, identical, side-by-side, movement or shear which can incorporate both push and pull; very similar methods and very similar results for the status of data at the time.

These notions of force are applicable today at the scale of continents, as Sealstone 1 was applied to the Taurus and Himalayan Mountain ranges. The sealstone method was used at the sub-continent level as a single unit of India, equal to Sealstone 2. Likewise, the Liguria/Italy/Peloponnese areas were moving sub-units covered by Sealstone 3. The Ancient Greeks used sealstones to describe the subdivision of the continents in their smaller Oikumene; we now call the same method continental drift, now we know their number, and I call Eratosthenes the first regional geologist. Ortelius' studies of Iceland, plus his accurate cartography drove him in the same direction of continental movements on his modern globe in 1596, as Carey did in 1956 (Carey 1958). Ortelius was the second regional geologist.

Geologic time

This paper has been written in chronological order to frame historic events in a logical time sequence; oldest event first and youngest last. Complicated geologic time terms to indicate relative 'ages' are unnecessary because it is still chronological, oldest rocks at the bottom of the pile and youngest at the top (unless they have been overturned.) By placing the youngest orange Mollasse (spelt 'Molasse') at the top of the legend in figure 6b, the simple stacking system of events works because the rocks were not overturned, except in local areas. However, the term Mollasse can be confusing; it refers to the coarse conglomerates deposited in front of rapidly rising and eroding mountains, a term used by Swiss geologists, not to be confused with molasses, a syrupy by-product of sugar! Geology is plagued by 'in-house terminology', yet continental drift is the over-arching natural evolution of the Earth and related, interested people should not be excluded. The colours in figure 6 appear on several geological time scales and on the legend of the UNESCO Geological Map of the World (Choubert *et al.* 1976), but are rarely used on American, British and Australian government survey maps; they want to be different while the author is trying to bring understanding of continental drift to any interested person.

Trading, shipping and mapping

Evolution of mapping was driven by, and for, shipping of spices then silk in the Indian Ocean by Mesopotamian and Persian Gulf nations in the northwestern Indian Ocean from 2400 BCE–1154 CE and by the Austronesians in Southeast Asia from Taiwan to Madagascar from c.1500 BCE–1154 CE. The reverse direction from the Atlantic by European countries eastwards via the Cape of Good Hope to the Indian Ocean from 1487 CE required finding better ways to define the shorelines or coastlines from which students of continental drift, amongst many others, can benefit.

ACKNOWLEDGEMENTS

I thank all who attended my field-based courses; I have learned from their questions raised at the outcrops and during the lectures in the western USA and Canada in 1974–1975 while with Exxon; 45 times from Wales to the North Downs, London from 1983–2012; and several times in Australia, Indonesia and Brunei. Sincere thanks to Julie Hawkins from 'In Graphic Detail' for her expert preparation of the figures, for the helpful comments of two referees and for input by Sally Bryant, the Royal Society's Editor. Special thanks for numerous discussions with close friends, the late Professor Carey, Ross Large, Warren Boyles, Ken Morrison, Ian Smith and Barry, my brother.

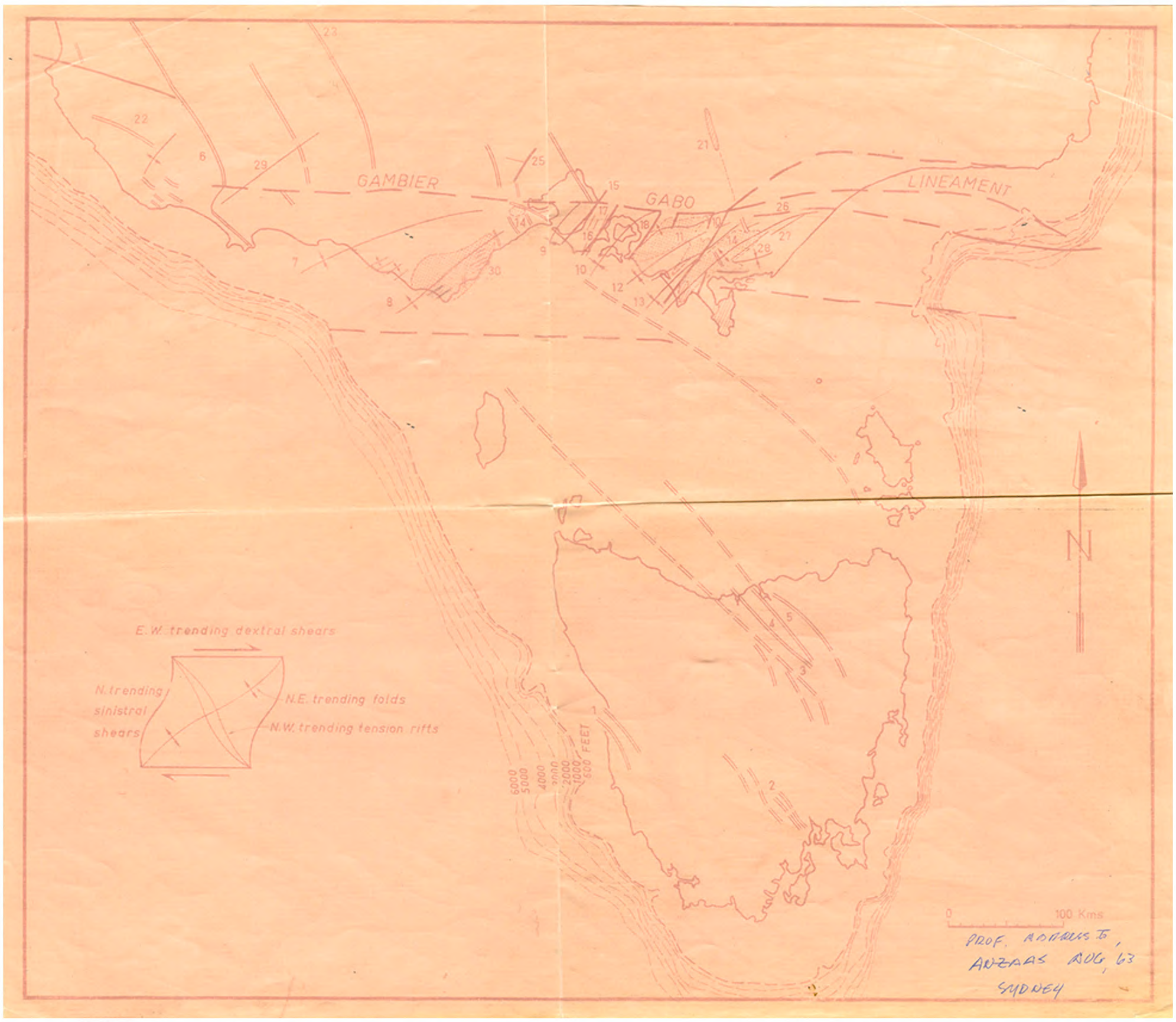


FIGURE 7 — Carey's original map he made for Lewis G Weeks in Connecticut in 1959 and presented at the ANZAAS Conference in Sydney in 1963 and subsequently given to the author in 1999. Carey published the same map in Carey (1986).

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